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PB-297 037

Areawide Waste Treatment and Water Quality Management Planning. Appendix C-3. Summary Report for the Southern Illinois 208 Mine Waste Control Program

Greater Egypt Regional Planning and Development Commission, Carbondale, IL

Prepared for

Environmental Protection Agency, Chicago, IL. Region V

Nov 78

PB 297037

Areawide Waste Treatment and Water Quality Management Planning

Summary Report for the Southern Illinois 208 Mine Waste Control Program

Appendix C-3

Franklin, Gallatin, Hamilton, Hardin, Jackson, Jefferson, Perry, Pope, Saline, and Williamson Counties, Illinois

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Areawide Waste Treatment and Water Quality Management Planning

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Summary Report for the Southern Illinois 208 Mine Waste Control Program

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Franklin, Gallatin, Hamilton, Hardin, Jackson, Jefferson, Perry, Pope, Saline, and Williamson Counties, Illinois

The preparation of this report was financed entirely with federal funds from the U.S. Environmental Protection Agency under grant number P005225-01 through a contract with the Greater Egypt Regional Planning and Development Commission. The contents do not necessarily reflect the views and policies of the Environmental Protection Agency, nor does mention of trade names or commercial products constitute endorsement or recommendation for use. Publication No. GERPDC-78-495a.

BIBLIOGRAPHIC DATA SHEET	1. Report No. GERPDC 78-495a	2.	3. Recipient's Accession No. PB297037
4. Title and Subtitle Areawide Waste Treatment and Water Quality Management Planning Summary Report for the Southern Illinois 208 Mine Wastes Control Program, Appendix C-3--Summary Report			5. Report Date November 1978 6.
7. Author(s) Energy & Environmental Analysis, Inc., Cambridge, Massachusetts			8. Performing Organization Rept. No.
9. Performing Organization Name and Address Greater Egypt Regional Planning and Development Commission P. O. Box 3160 Carbondale, Illinois 62901			10. Project/Task/Work Unit No. 11. Contract/Grant No. P005225-01
12. Sponsoring Organization Name and Address U. S. Environmental Protection Agency Region V 230 South Dearborn Chicago, Illinois 60604			13. Type of Report & Period Covered Final 14.

15. Supplementary Notes

16. Abstracts

The Summary Report for the Southern Illinois 208 Mine Wastes Control Program is Appendix C-3 of the Areawide Waste Treatment and Water Quality Management Plan for Southern Illinois. The report was prepared under section 208 of the Water Pollution Control Act, as amended. The report presents a simulated computer model of the mine waste control program in Southern Illinois.

17. Key Words and Document Analysis. 17a. Descriptors

Coal, Water Pollution, Water Quality, Reclamation, Coal Mining, Computer Model, Mine Inventory

17b. Identifiers/Open-Ended Terms

17c. COSATI Field/Group

18. Availability Statement	19. Security Class (This Report)	21. No. of Pages
National Technical Information Service U.S. Department of Commerce Springfield, VA 22151	UNCLASSIFIED	106
	20. Security Class (This Page) UNCLASSIFIED	22. Price A06-A01

FORM NTIS-35 (REV. 3-72) THIS FORM MAY BE REPRODUCED USCOMM-DC 14952-P72

VOLUME I - SUMMARY REPORT

FOR THE:

SOUTHERN ILLINOIS 208

MINE WASTE CONTROL PROGRAM

Submitted to:

The Greater Egypt Regional Planning
and Development Commission
P.O. Box 3167
Carbondale, IL 62901

By:

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March, 1978

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November 1978

Michael P. Mauzy
Acting Director
Illinois Environmental Protection Agency
2200 Churchill Road
Springfield, Illinois 62706

Dear Mr. Mauzy:

The Commission is pleased to transmit Appendix C-3, Summary Report for the Southern Illinois 208 Mine Wastes Control Program - Summary Report of the 208 Areawide Waste Treatment and Water Quality Management Plan for Southern Illinois. The plan and this document cover the ten Illinois Counties of Franklin, Gallatin, Hamilton, Hardin, Jackson, Jefferson, Perry, Pope, Saline, and Williamson.

This technical report is an integral part of the Southern Illinois Water Quality Management Plan that is designated to meet the contract requirements of Federal Grant Number P005225-01 under the U. S. Water Pollution Control Act Amendments of 1972, as administered by the United States Environmental Protection Agency.

We trust this submittal of this report, as well as the others comprising the plan, will provide the basis for certification of the plan and continued designation of this area.

Sincerely,

A. S. Kirkikis

A. S. Kirkikis
Executive Director

ASK:db

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ADDENDUM

Shortly after completion of the mine waste control program analysis, authors received data indicating potential errors in the mine waste inventory data files supplied to the project from the co-operative Wildlife Research Laboratory. Throughout the project and in full agreement of the Illinois Environmental Protection Agency (IEPA) and the U.S. Environmental Protection Agency and all other concerned parties, the data supplied from the Research Laboratory was considered primary information, correct as supplied and not checked due to project constraints. Recent correspondence from the Laboratory indicates a potential for random decimal place errors in recorded acreages of "gob" and slurry, in the data supplied to the project. A few errors were indicated in the correspondence, but it was alluded that there may be more. The errors indicated were located in the Middle Fork of the Saline River, placing too much "gob" and slurry in this sector.

Presently parts of the Middle Fork of the Saline River, especially those sectors adjacent to the reported errors cannot be properly calibrated using the simulation model. The model although close, predicts average pH and net alkalinity values lower then expected from actual monitoring data. Removal of the erroneous acreages would greatly improve the model calibration for this sector.

ADDENDUM

Based on commentary received during the Mine Waste Committee meeting held at the Greater Egypt Regional Planning and Development Commission Offices in Carbondale, Illinois, on April 18, 1978, the Water Quality Task Force meeting held at the Holiday Inn in Marion, Illinois, on April 19, 1978, and commentary received by various agencies in the form of letters and other communication, the following addendum has been drafted. The addendum is primarily aimed at clarification of certain points, and is not intended to change or alter the report's structure in any fashion.

ITEM 1: A question was posed as to the utilization of the hydrologic fill-in procedure presented in Chapter 5.

RESPONSE: The hydrologic fill-in procedure was used to complete USGS gaging records for the eight gages used throughout the study area in order to provide a 68 year record. The long term record so generated was used to establish a recent short period of record that would be considered to be statistically representative of the larger set. Analysis of the gaging record data indicated that the period extending from 1963 through 1975 totalling twelve years would be statistically representative, and was used in the modeling analysis.

ITEM 2: A question was raised as to the handling of mine waste sources listed as partially or totally covered in the listing supplied to the project by the Cooperative Wildlife Research Laboratory, Carbondale.

RESPONSE: Although it is true that the Cooperative Wildlife Research Laboratory-Carbondale surface and underground mines inventory listings supplied to the project indicated areas of "gob" and slurry exposed and covered separately, coverage does not necessarily imply elimination of pollutional discharges. During the early stages of the 208 project this point was discussed in detail with the Mine Waste Committee and agreement was reached that coverage and vegetative cover was not synonymous with zero discharge for "gob" and slurry areas. This fact was further iterated in reviews of reclamation projects conducted in the 208 and other mine waste impacted areas. Additionally the scope of the 208 study was never intended to monitor each of the 269 sources inventoried to assess pollutant discharges. For these reasons all sources listed as barren or covered were considered to be possible discharge points and included in the analysis.

ITEM 3: A question was raised in reference to the meaning of the term "affected area" as used in the mine waste analysis.

RESPONSE: Affected area, as defined in the mine waste analysis, included all surface area affected via excavation due to surface coal mining activities. Areas of "gob" and slurry were not included as part of the affected area. In the analysis of futures it was assumed that all surface mine related "gob" and slurry would be located either at the preparation site or would be hauled back to the strip pit for disposal. Therefore no significant additional "gob" or slurry were considered as pollutional sources due to future mining activities.

ITEM 4: A question was raised as to the implication in Volumes I and II of the report that limestone ($caCO_3$) produced sulfate compounds, and that the estimation of sulfate loadings used in the futures analysis was unreasonable.

RESPONSE: The sulfate issue is certainly one of complexity, and admittedly is presented in an abbreviated fashion in the text. The abbreviation of explanation has led to some misconceptions as to what was meant. The implication was never that sulfates were produced from limestone, but simply that the reaction presented categorizes a change in state from free acid as H_2SO_4 to partially soluable $CaSo_4$. The sulfate analysis procedure as used on the samples collected during the 208 sampling program is subject (as noted in Standard Methods) to significant interference in the presence of high iron concentrations. Since the neutralization process can cause iron precipitation, the level of interference, and therefore measured sulfate, can be biased.

In reference to the high sulfate yields used in the analysis of futures, Table 1A presents the data used in generating the loads. The sulfate yields presented were computed from the actual 208 monitoring data for the stations indicated. Presented on the table are: values of overall sulfate yield in lbs/acre/day, the coefficient of variation of the measured data, the 90 percentile maximum level, the sulfate yield scaled to reflect the average yield per affected acre per tributary area, and the 90 percentile maximal level of the scaled emissions. Analysis of the scaled average emissions of sulfate yield per affected acre and 90 percentile level of the affected area yield was used to estimate future loadings. In the analysis, the "gob" and slurry sulfates contribution was computed and subtracted from the total yield to describe emissions based solely on affected area. The analysis of the futures residuals assumed that for the first year after a particular sector was stripped, its sulfate emissions would be at a 100 percent level.

During subsequent years the sulfate emissions would be attenuated by the functions presented in Volume II of the report. Without any further data from other studies, the authors feel that the approach taken was quite reasonable.

ITEM 5: A question was raised as to the legality of the back-filling and blind flushing option under PL 95-87, in that blind flushing would necessitate the introduction of water into abandoned undergound mines.

RESPONSE: Although PL 95-87 specifically excludes the introduction of any waters into abandoned underground coal mines the authors believe that the option of backfilling and blind flushing abandoned "gob" into such works is potentially feasible and should be considered. Recent data generated by the U.S. Bureau of Mines on some experiments conducted in Pennsylvania and Wyoming has indicated that backfilling and blind flushing of "gob" into abandoned underground works is economically feasible, and if properly applied, can be a good pollution control measure. It can also help reduce subsidence problems.

Although, at this point, the option is not legal due to Federal requirements, it is still considered to be viable, especially when coupled with the dual benefit of subsidence control around population centers where subsidence could pose a serious threat to the local populace.

ITEM 6: A question was raised as the potential for mine waste inventory errors as indicated in the initial Addendum included in Volumes I and II of the overall report.

RESPONSE: Initial correspondence from the Cooperative Wildlife Research Laboratory-Carbondale indicated the potential for random decimal point errors in acreages of "gob" and slurry in data supplied to the project. Since that time, when the original Addendum was drafted, information supplied to the project from the various coal companies has indicated only two errors in the data file, both within a relatively small sector of the Middle Fork of the Saline River. The particular sector (the area around model node 18) was a sector where model calibration was not as good as would have been desired. Removal of the errors would improve the model calibration for this small zone. Since no further errors have been indicated by the various coal companies after scrutiny, the authors are confident that the number of data errors is quite small and will not impair the reliability of the overall analysis.

TABLE 1A: ANALYSIS OF SULFATE YIELD

(1)	(2)	(3)	(4)	(5)	(6)	(7)	(8)	(9)
NC-03	178,770	8.6	147,843	.48	.83	2.1	9.8	24.2
NC-02	366,536	7.5	203,761	.70	.54	1.4	7.2	18.0
NCDP-07	12,812	14.8	1,104	.55	.08	.2	.6	1.4
NCDP-02	11,212	37.2	26,715	.65	2.38	5.9	6.4	15.9
NCD-01	99,219	8.3	265,627	.70	2.67	6.7	32.1	80.3
NCP-04	18,889	41.1	38,856	.35	2.04	5.1	4.9	12.4
NEJ-06	9,924	7.8	3,705	.55	.37	.9	4.7	12.0
NGW-01	5,569	40.9	23,173	.30	4.13	10.3	10.1	25.2
NF-01	12,952	8.7	11,607	.35	.92	2.3	10.5	26.3
NCJ-01	3,184	26.8	25,757	.30	8.13	20.3	30.3	75.8
NCJ-05	10,250	26.6	7,298	.30	.71	1.8	2.7	6.7
NDJ-01	2,893	4.9	28,591	.50	9.88	24.7	201.5	503.9
NG-03	62,357	4.9	94,066	.35	1.50	3.7	30.6	76.4
NCP-01	6,223	2.4	14,962	.25	2.42	3.9	100.7	251.8
ATH-05	85,173	7.6	194,926	.65	2.29	5.7	30.1	75.4
ATH-01	154,455	5.4	283,491	.65	1.87	4.7	34.7	86.8
ATH-10	2,176	14.1	8,419	.50	3.88	9.7	27.5	68.7
ATGC-02	27,738	32.1	88,118	.40	3.17	7.8	9.8	24.7
ATG-03	149,852	6.8	286,534	.50	1.92	4.8	28.2	70.5
AT-05	354,500	5.8	415,232	.45	1.17	2.9	20.1	50.3
ATE-03	8,822	6.2	15,754	.55	1.79	4.5	28.9	72.2

Legend

(1) 208 Sampling Station
(2) Acreage Tributary to Station
(3) Percent Affect Area
(4) Average Mass of Sulfate at Sampling Station
(5) Coefficient of Variation of Sulfate Loadings
(6) Average Sulfate Yield (lb/acre/day) at Sampling Station
(7) Extreme Sulfate Yield (lb/acre/day) Computed as Mean + 3 Standard Deviations*
(8) Average Sulfate Yield (lb/acre/day) Scaled on Basis of Affected Acreage
(9) Extreme Case of Sulfate Yield (lb/acre/day) scaled on Basis of Affected Acreage

*The utilization of the mean plus 3SD to denote an extreme probabilistic level derives from "Chebyshev's Inequality" which states that the probability of non-exceedance for any random variable of unknown distribution is given by $1-1/t^2$, where t = # standard deviations. The 90% level commonly used in water resources and environmental engineering is computed at 3t.

SOUTHERN ILLINOIS REPORT - ERRATA
VOLUME I

Page	Line	Error	Correction
Addendum	2	analysis, authors	analysis, the authors
Notice	6	hearings the summary	hearings on the summary
"	7	1978	1978,
"	14	data as well	data, as well
"	16	the document	Volume II
1	11	The mine waste	- start new paragraph -
1	23	these	those
8	21	pollution	pollutant
9	13	operation,	operation, and
12	1	parameters considered	parameters were considered
14	6	"Strike Force"; information	"Strike Force" information;
15	2	abandoned mines	abandoned underground mines
17	ftn.	Bureau of Mines...	Department of Mines...
24	21	indentified	identified
25	16	Upstream of Confluence	upstream of confluence
26	17	and more...leading process.	and can yield high concentrations of gypsum ($CaSO_4$)
30	9	Confluence	confluence
33	1	o Lake	to Lake
33	4	Confluence	confluence
35	4	Confluence	confluence
37	4	Confluence	confluence
37	7	Confluence	confluence
38	5	pH as well	The pH as well
38	15	Crab Orchard	The Crab Orchard
39	5	Confluence	confluence
42	19	Lake,	Lake
47	8	Upstream of Confluence	upstream of confluence
50	9	Upstream of Confluence	upstream of confluence
52	8	markedly occurring	markedly
52	24	Fork	Fork.
53	24	period.	periods.

NOTICE

This report is a revised edition, in final form of the "Summary Report of the Southern Illinois 208 Mine Waste Control Program," submitted to the Greater Egypt Regional Planning and Development Commission (GERP&DC) in January of 1978. The report as prepared at that time was a presentation summary document of the then forthcoming final report. Subsequent to the public hearings the summary report, held at the GERP&DC offices in Carbondale on February 4, 1978 modifications were made as presented in this document. In its final form, the document acts as Volume I of a three volume series reporting findings of the mine waste control program. The document is intended as a summary only, primarily for public distribution. Volume II of the series entitled "Technical Report of the Southern Illinois 208 Mine Waste Control Program" presents some of the same materials found in the summary report coupled with extensive detailing of all procedures, assumptions and data as well as an appendix including a listing of the computer model and a user manual.

The intent of the document is to provide a complete and open file on all activities of the project for scrutiny by the technical personnel of all agencies interested in the findings.

REPORT PREPARATION

This report was prepared by Energy and Environmental Analysis, Inc. (EEA). Dr. William C. Pisano was the project manager and in conjunction with Mr. Gerald Aronson, Senior Project Engineer, co-authored this summary document. Mr. Aronson supervised all inventory, mapping and mine waste control delineation components of this project. Dr. Pisano, Abraham Lederman and Celso Queiroz performed all the water quality simulation analyses and other related computational efforts. David Watson, Karlson Greene, Nora Scanlan and Robert Noonan also contributed in the preparation of this document.

The initial mine waste simulation model methodology was prepared by GKY & Associates, Arlington, Virginia, under subcontract to Energy and Environmental Analysis, Inc. The simulation model was then refined by EEA and formed the basis of all simulations conducted in this study.

ACKNOWLEDGMENTS

Energy and Environmental Analysis, Inc. would like to extend thanks to the 208 planning staffs of Greater Egypt Regional Planning and Development Commission and the Southeastern Regional Planning Commission and Development for their help and cooperation in the preparation of the inventory data necessary to develop the mine waste program for the area.

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INTRODUCTION

This report is the first volume or summary section of three volumes presenting the results of a two year effort aimed at assessing the acid mine drainage impacted area within Southern Illinois. Volume II of the series is entitled "Technical Report of the Mine Waste Control Program of the Southern Illinois 208 Study" and presents the details of the planning effort. Volume III is a mapping section presenting a compilation of all inventory maps assembled during the study. The study area was comprised of the ten counties of Franklin, Gallatin, Jackson, Jefferson, Hamilton, Hardin, Perry, Pope, Saline and Williamson. The study focused on developing a methodology and plan for rational assessment and reasonable application of control technology for controlling mine wastes throughout the area. The mine waste problem presently occurring in Southern Illinois is one of extreme complexity. Coal mining by surface and underground methods has been practiced in the area for roughly 150 years[1]. Sources of acid mine drainage number in the hundreds, causing significant degradation of a large percentage of the areas' waterways. Increased coal production promoted by the present national energy crisis could cause even further stream quality degradation without the most careful controls. The United States Environmental Protection Agency clearly recognized the severity of the problem and funded the Greater Egypt Regional Planning and Development Commission (GERP&DC) under section 208 of the 1972 Clean Water Act PL 92-500, to conduct this study.

The 208 Plan so developed focuses on upgrading existing water quality through reclamation of mine related pollution sources, especially these pertaining to past mining activities, utilizing monies generated under the Surface Mining Control and Reclamation Act of 1977, PL 95-87[2], providing for a national reclamation fund based on a surtax on all present and future coal production.

SECTION I. COAL - A PERSPECTIVE

A. Coal and the Energy Crisis

The energy crisis currently facing the United States and other industrial nations of the world is, as President Carter recently stated, not a short term phenomenon. Present energy forecasts indicate a dire shortage of domestic oil and natural gas within the next decade. It is also forecast that alternative fuel sources such as: solar, wind, and geothermal will not be available in time to meet the needs, and do not have the long term potential generation capacity to serve as ultimate solutions. Fortunately, the United States has been blessed with vast coal reserves. Current estimates indicate that coal reserves are within the range of three trillion tons[3,4], an amount sufficient to sustain this nation for several hundred years at present consumption levels. To date, very little of the U.S. coal reserves have been tapped. To temporarily meet the upcoming energy demand a national energy policy has been proposed by the President[5]. The policy focuses heavily on utilization of coal as a short term solution, with development of alternative energy sources and new coal energy extraction technologies as the ultimate goal for establishing U.S. energy independence.

Locally, Illinois has the largest reserves of bituminous coal of any state in the union, with only North Dakota and Montana having greater total reserves. The North Dakota and Montana coal is lignite and subbituminous yielding a relatively low heat value per pound[6,7]. Illinois State Geological Survey estimates indicate mineable reserves remaining in the ground at roughly 160 billion tons. This figure is exclusive of an additional amount in excess of 100 billion tons that are considered to be too deep to be economically extracted with present technology.

The Southern Illinois 208 area is located above the southwestern tip of a geological structure called the Illinois Basin. This basin is comprised of many layers of sedimentary strata, and can be visualized as a giant laminated spoon underlying parts of Indiana and Western Kentucky, as well as most of Illinois. Around the edge of this basin, the spoon's rim is close to the surface, and the layers of the spoon comprise the coal that may be surface mined. Toward the center of the spoon, the layers may be 1000 feet or more beneath the surface, and the coal requires underground extraction techniques. The "spoon" analogy* may be continued: the slope of the spoon's surface toward the center of the basin is steepest near the back of the spoon, where the handle would join, and shallowest at the tip. In the Illinois Basin, the spoon's tip is in northern Illinois, and the imaginary handle might join the basin near the Williamson County community of Crab Orchard. Thus, the Southern Illinois 208 area may be viewed as Illinois' share of the base of the spoon, where the geological dip of the rocks is relatively steep, and the area available for surface and shallow underground mining is restricted by this steepness.

It would be logical to assume therefore that coal production in Illinois would be somewhat uniformly distributed throughout the lower half of the state with surface mining being largely employed in the south and deep mining further north. This is not the case, however, since the relative importance of the 208 area's coal resources within the Illinois Basin is significantly increased by three attributes of its coal. First, the major coal seams tend to be thicker within the 208 area than in the northern sectors.[7,4] Secondly, the relative heating value per pound of the coal increases from northwest to southeast placing the majority of the high yield coal in

*Analogy generated by the Greater Egypt Regional Planning and Development Commission staff.

the 208 area and thirdly, of the limited supplies of low sulfur coal within the state over half are within the 208 boundaries.[7,8,4] Analysis of published data indicates that the 208 area contains about 17% of Illinois' total coal resources and less than 13% of its surface mineable resources, but roughly 55% of its low sulfur coal, making the area most attractive for increased production.

Historically, the first coal mines developed in Illinois were located in Jackson County, starting around 1810. By 1898, there were 889 mines operating in 52 counties with an annual coal production of 23 million tons.[1] Today modern mining methods have increased the productivity of individual mining operations to the point where according to the 1975 Illinois Bureau of Mines and Minerals' Annual Coal Report[9], there were 57 active mining operations producing 59,539,019 tons of coal in 1975. Of this total roughly half, or 30.4 million tons were produced within the 208 study area. Future projections of coal production show rapidly increased production for the area for a long period, extending until at least 1995.

B. Water Quality Issues

Unfortunately, coal as many other resources, cannot be tapped using present technology without some sacrifice to the environment. Congress and the President were fully aware of this fact in passing the Surface Mining Control and Reclamation Act of 1977, Public Law 95-87. This act sets up a national fund based on generation of revenues from future coal production to restore areas of past degradation, carefully monitor new operations and research and develop alternative control technologies. Mining by surface or underground methods is not an ordinary industry. Unlike their other industrial counterparts, mines do not operate at fixed locations since they

are continually moving or expanding to reach new resources.* [10.11] Under such conditions even the most carefully designed and executed mining operation is subject to daily changes to meet varying operational requirements. In the case of coal mines, the situation is further complicated due to varying coal seam thickness and depth over short stretches of terrain. Coal mining by its very nature upsets the balance of nature, often causing degradation of water quality to the surrounding area. Due to the variability of mining conditions and rainfall patterns, pollutant discharges from mining activities vary widely, necessitating careful examination of many parameters such as soils, coal seam conditions and mining methods.

Pollution due to coal mining emanates primarily from three sources: runoff from the affected or spoil areas (surface mining only), runoff from poorly contained waste or "gob" piles and runoff from improperly operated or abandoned slurry ponds.** During surface mining operations large volumes of earth and rock or spoil are removed to expose the coal seams being mined. Mining techniques using area mines such as those found in Southern Illinois, call for spoil to be piled in a continuous pile adjacent to the trench or pit, in the form of a large mound or spoil bank. The spoil bank is exposed to the atmosphere and precipitation and is often subject to considerable runoff and soil erosion. Additionally, spoil in some areas can contain significant levels of various pollutants especially acid compounds. Therefore, precipitation falling on an acidic spoil bank or affected area can cause acid runoff to the adjacent waters.***

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*Although this statement is true for all types of mines, the actual surface impacted area due to underground mining activities remains at somewhat fixed locations. Even so the quality of materials extracted in an underground activity and brought to the surface can vary significantly.

**Primarily older or abandoned sources.

***Unregulated under all past laws.

During the natural formation process of coal, many impurities are entrapped within the coal seam and its surrounding layers. Primary impurities or pollutants include: metals, chemical salts and pyritic compounds.[12,13,14,15,16,17] Most coal that is mined must undergo a cleaning operation to remove some of the dirt and impurities present within the coal seam as well as any of the materials surrounding the coal seam that were picked up during the mining process. Impurities form the reject or unmarketable portion of the materials removed in the mining operation. Modern coal cleaning processes remove impurities in two steps: removal of the large materials commonly referred to as "refuse" or "gob", and wet floatation and removal of the fine reject material, usually 20 mesh or smaller, in the form of slurry which is then piped to an enclosed lagoon or impoundment. Disposal of refuse varies with the type and extent of the mining operation. Typically coal extracted during a modern operation is trucked to a preparation plant, cleaned and the resultant "gob" returned to the open strip pit for burial with the spoil.*

Unfortunately, many surface mine operators in the past did not follow this practice, instead opting to simply pile the "gob" in random piles. Entrapped pyritic compounds in the "gob" react with oxygen in the air through a complex chemical process ultimately forming concentrated sulfuric acid which then leaches out of the piles and enters adjacent waters through overland runoff and seepage. The acid mine drainage (AMD) thus formed also contains significant quantities of iron and other compounds,** often causing severe water quality degradation in the surrounding area if not properly contained. Continuous decomposition of the clay, shale and sandstone entrapped in "gob" results in

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*The authors agree that present practice allows for containment of most "gob" pile and slurry pond emissions within the confines of the preparation plant. Even so some amount of "gob" will inevitably be deposited around the mining site during the handling process.

**The actual composition of the AMD from one given source to another will vary with respect to types and concentrations of "other" compounds.

high degrees of erosion which then expose new pyritic surfaces to the atmosphere for continued acid production. This process forms a continuous cycle of oxidation, leaching, erosion and finally, renewed oxidation, resulting in a seemingly inexhaustable and continuous source of acid production.[18] The problem with underground mining activities is even more complex in that "gob" generated from such operations is typically disposed of by piling the waste in the nearest adjacent field, since most often no large disposal sites are readily available nearby.* Slurry lagoons associated with coal cleaning operations present a similar though less severe environmental problem. The lagoons contain fine waste material from preparation plants and can be composed of as m[illegible] 50% coal, especially from older operations. The balance of the slurry contains similar materials as "gob" thus yielding an additional significant source of acid mine mine drainage pollutant if the slurry pond is not maintained and allowed to overflow.

Although the primary pollutant from mining activities is acid drainage, acid runoff from mine impacted areas or refuse piles often is neutralized by naturally-occurring alkaline substances especially, limestone. The neutralization process may be represented in the following simplified form:

$$3\ CaCO_3 + 2\ Fe\ SO_4 + H_2SO_4 + 0.5O_2 + 2H_2O \rightarrow 3\ CaSO_4 + 2\ Fe(OH)_3 + 3CO_2$$

The above reaction pertains to mine drainage waters containing iron as ferrous sulfate ($FeSO_4$) and free sulfuric acid H_2SO_4 which is reacting with either natural or agricultural limestone, calcium carbonate ($CaCO_3$).

*This practice has been stopped under present State and Federal regulations and pertains primarily to older generally abandoned operations.

This case is certainly typical of mine wastes within the study area. Products of the reaction are Ferric Hydroxide $Fe(OH)_2$ or "yellow boy," Calcium Sulfate ($CaSO_4$) or gypsum and Carbon Dioxide (CO_2) which is given off as a gas. Many other reactions can and do occur during the neutralization process. It is not the purpose of this section to present a comprehensive review of mine drainage chemistry. The acid neutralization reaction as shown is the most significant in the formation process of sulfates[13,19,20,21] and "yellow boy." Sulfates thus produced are in the form of partially soluable gypsum, often resulting in high concentrations of sulfate compounds in the receiving water body* and precipitation or settling of the entrained dissolved iron in the form of the familar "yellow boy." Precipitation of "yellow boy" leaves a coating on stream beds, often smothering bottom dwelling organisms and reducing the diversity of species especially vertibrate organisms within the impacted watercourses.[18,22,23,24]

Presently there are roughly 269[25] individual active or abandoned "gob" and slurry disposal sites within the 208 area. According to IEPA estimates, acid runoff from these sites has caused severe water quality degradation of hundreds of river miles within the area[1], greatly inhibiting the diversity of aquatic life[26] as well as making them unsuitable for potential public surface water supplies. In order to protect the environment from further undo harm, the first of a series of Illinois regulations aimed at controlling pollution emissions from mined areas as well as improving the aesthetic value of strip mined lands was adopted in 1962. The regulations were increased in stringency and coverage in 1967, 1971, 1972, 1976 and most recently in 1977. Present coal mining operations within the state are required, in essence, to dispose of all polluting waste and reclaim all mined areas to a level of potential

*This point has been reiterated by representatives of the coal operators as well as review of long term IEPA and 208 collected water quality data for the area. Concentrations of up to 2500 mg/ℓ are possible.

utilization similar to that before mining. Even with the present mining controls some pollutant discharges from active mining areas must be expected, however small.* Although the pollutant emissions will be considerably decreased from those resulting from older operations, the cumulative effect of increased mining productivity could still cause severe water quality degradation in water quality constrained segments.

This is not to say that there exists a direct correlation between increased mining activity and conditions of water quality degradation. Truly, increased mining activities will cause some increase, however small in pollutant emissions to adjacent waters. The actual impact of the increased pollutant discharges to the adjacent waters is subject to numerous site specific variables such as: location of mine, characteristics of overburden, characteristics of coal seam(s) being mined, type of mining operation, receiving water flow and quality. In some cases where new mining activities are being conducted in areas of extensive prior activity, water quality could actually improve due to reclamation of the existing sources in the area as part of the present operation or mining permit requirements. In other cases such as Beaucoup Creek, extensive new mining activities are projected in relatively virgin areas.[7] In that case the cumulative effect of the new mines could cause water quality problems on some sectors. This problem has been carefully addressed as part of the overall 208 mine waste control program and the results are presented in summary in section 5 of this report and in detail in Volume II, the Technical Report of this study.

*A pragmatic hypothesis by the authors, based on review of current mine sites and discussions with coal company representatives, and regulatory officials.

SECTION II. THE SOUTHERN ILLINOIS 208 MINE WASTE CONTROL PROGRAM

A. Program Overview

The Southern Illinois 208 area faces a problem of extreme complexity in attempting to address the problem of acid mine drainage. To aid in assessing the problem and to develop a rational and reasonable approach for restoration of the areas' waterways to acceptable quality levels, the 208 mine waste program was developed. Program elements included: inventorying all mine waste sources within the Big Muddy and Saline River Basins; conducting a long-term sampling and flow gaging program to provide water quality data throughout the two watersheds, and development of a computer-based simulation model of the two river systems to allow for assessment of water quality for both present and future projected conditions as well as assessment of reclamation and mine waste control feasibility throughout the area. Figure 1 is a block diagram of the mine waste control project in all phases. The program began in January of 1976 with activities extending until January 1978. The data collection phase of the project extended for almost one and one half years from program initiation.

Since acid mine drainage was the focus of the study and since it was possible to generate definite relationships between pH, net alkalinity and sulfate compounds in the water to land use attributes, these parameters formed the primary focus of the study.* Other pollution parameters such as iron, manganese, total dissolved solids,** and heavy metals were monitored during the various sampling programs, but not considered in the simulation model due to the extreme complexity of in-stream physical and chemical reactions making it impossible to address these parameters on an areawide basis. The three

*The pH, net alkalinity and sulfate correlations were done on a sub-regional basis within the study area to reflect localized geological conditions. No one good relationship exists for the entire 208 area, therefore necessitating this type of approach. The regionalization concept and pH/net alkalinity relationships are presented in detail in Chapter 5 of the Technical Report, Volume II of this series.

**Total dissolved solids actually was considered, but not used as a formal parameter.

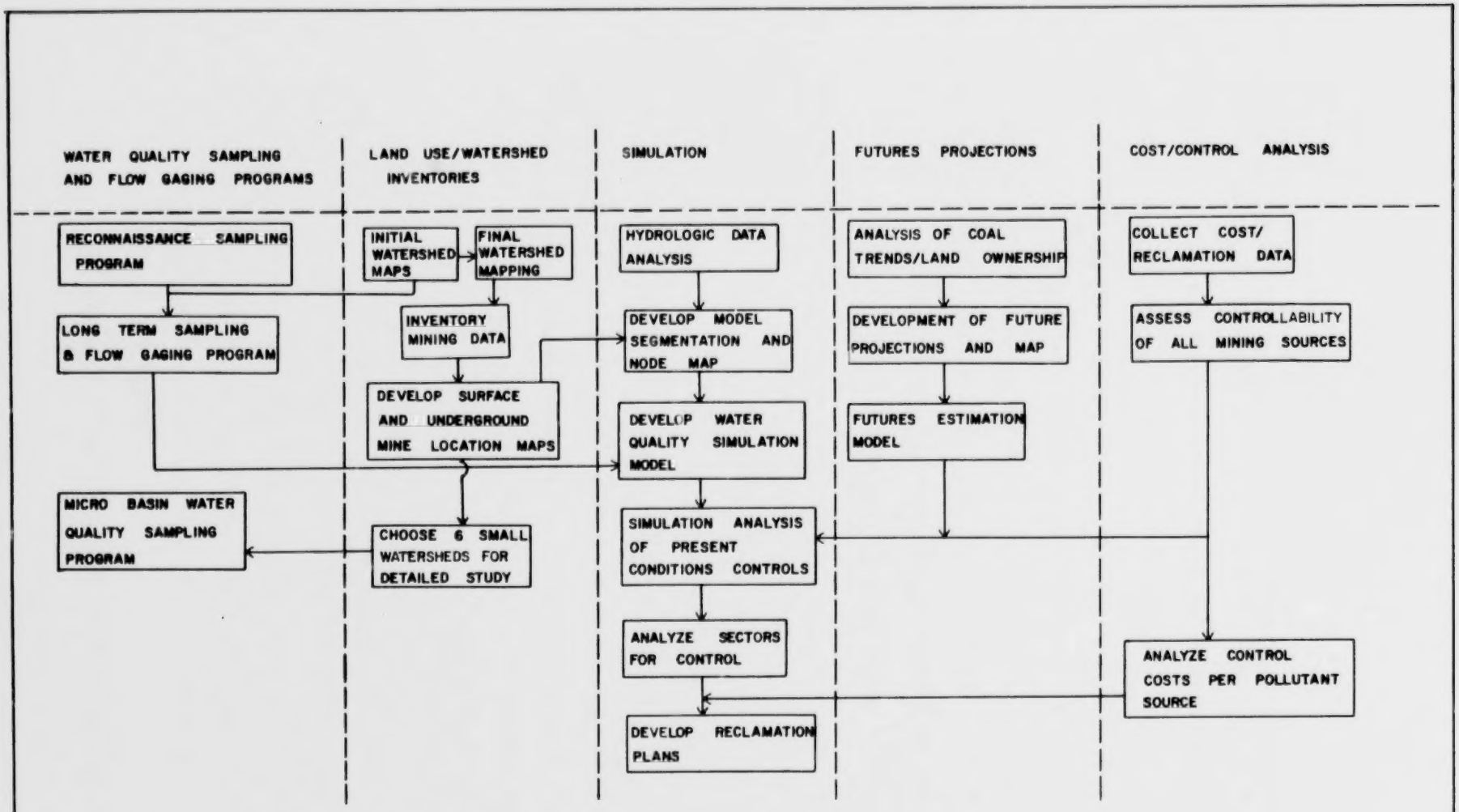
WATER QUALITY SAMPLING AND FLOW GAGING PROGRAMS
LAND USE/WATERSHED INVENTORIES
SIMULATION
FUTURES PROJECTIONS
COST/CONTROL ANALYSIS
RECONNAISSANCE SAMPLING PROGRAM
INITIAL WATERSHED MAPS
FINAL WATERSHED MAPPING
HYDROLOGIC DATA ANALYSIS
ANALYSIS OF COAL TRENDS/LAND OWNERSHIP
COLLECT COST/ RECLAMATION DATA
LONG TERM SAMPLING & FLOW GAGING PROGRAM
INVENTORY MINING DATA
DEVELOP MODEL SEGMENTATION AND NODE MAP
DEVELOPMENT OF FUTURE PROJECTIONS AND MAP
ASSESS CONTROLLABILITY OF ALL MINING SOURCES
DEVELOP SURFACE AND UNDERGROUND MINE LOCATION MAPS
DEVELOP WATER QUALITY SIMULATION MODEL
FUTURES ESTIMATION MODEL
MICRO BASIN WATER QUALITY SAMPLING PROGRAM
CHOOSE 6 SMALL WATERSHEDS FOR DETAILED STUDY
SIMULATION ANALYSIS OF PRESENT CONDITIONS CONTROLS
ANALYZE SECTORS FOR CONTROL
ANALYZE CONTROL COSTS PER POLLUTANT SOURCE
DEVELOP RECLAMATION PLANS

FIGURE 1

THE SOUTHERN ILLINOIS 208 MINE WASTE CONTROL PROGRAM

parameters considered to act not only as primary indicators of pollution, but often serve as well as suitable indicators for other mine waste related pollutants.*

B. Water Quality Sampling Programs

From March to December 1976 a series of three sampling programs were conducted to provide stream water quality data necessary for the evaluation of water pollution within the area as well as provide information necessary for the calibration of the water quality simulation model. All sampling and flow gaging was conducted by the Greater Egypt Regional Planning and Development Commission (GERP&DC) staff with sample analysis being conducted by the Illinois Environmental Protection Agency at their Marion, Illinois laboratory. Sampling program development, staff training and overall co-ordination was provided by the consultants for the mine waste control program, Energy and Environmental Analysis, Inc. (EEA).

In March 1976, 116 sites throughout the two river basins were chosen as sampling points for a reconnaissance or exploratory water quality assessment program. Samples were analyzed for pH (both in the field and laboratory) sulfate, total iron, manganese, mercury, zinc, cadmium, total dissolved solids, hardness (calcium and magnesium) and net alkalinity. Data from the reconnaissance program provided baseline information for developing the long term 208 sampling efforts.

During the period of March through May 1976, initial watershed maps of the two basins were developed to aid in the assessment of sampling station locations to be used in the long term measurement program. In May of 1976 the sampling program was finalized and initiated. A total of 63 stations were chosen, 39 in the Big Muddy Basin and 24 in the Saline Basin. From

* A 0.98 correlation between TDS and sulfates was found to exist for IEPA and 208 collected data from the study area.

that point until December 7, 1976 each site was sampled* approximately 22 times yielding a total of almost 1400 samples collected. At each sampling, flow in the stream was determined to allow for analysis of total pollutant mass within the watersheds. Each sample was analyzed for: temperature, pH (in the field), net alkalinity, total iron, hardness (both calcium and magnesium), sulfates, total dissolved solids and total suspended solids. Manganese, mercury, zinc and cadmium were not considered due to their low concentrations found in the reconnaissance program as well as analytical constraints imposed by IEPA.

In order to provide detailed water quality data on discharges from actual sources, a micro-cell or small watershed intensive sampling program was conducted from January 1 to May 5, 1977. The purpose of this program was to provide baseline data for the detailed examination of five** small watersheds as well as provide some rainfall oriented information for use in assessing the simulation model results. A total of 42 sampling stations were chosen for this program. Each site was sampled at least six times with a total of 327 samples being collected. All samples collected were analyzed for the same parameters as listed for the long-term program. In sum, the three sampling programs yielded a total of approximately 14,800 water quality data points plus 1,725 flow determinations*** providing an extensive data base for later use.

C. Inventorying of Baseline Data

Occurring concurrently with the sampling program was a large scale inventorying program aimed at collecting mining, land use, cost and reclamation data necessary for the simulation and overall mine waste analyses. Data on

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*All samples taken during the 208 program were grab samples taken at roughly mid stream and mid depth (similar to IEPA Procedure).

**Actually six watersheds were considered although one was the combination of two smaller sectors.

***Actual procedures used are described in detail in a GERP&DC report entitled "208 Monitoring Procedures" and summarized in Volume II of this series.

locations and extent of surface and underground mines and associated other pollution sources was generated through an exhaustive procedure compiling information supplied to GERP&DC from: The Co-operative Wildlife Research Laboratory of Southern Illinois University - Carbondale[27]*; Illinois Department of Mines and Minerals aerial photographs and data files; Illinois Environmental Protection Agency (IEPA) "Strike Force"[28]; information analysis of GERP&DC aerial photographs; and field inspections of abandoned mine sites. The compiled information has been tabulated into a complete data file which is presented as part of the Technical report (Volume II) of the project. Data for assessing other land use parameters were prepared from analysis of aerial photographs and existing demographic data by GERP&DC.

In order to provide accurate forecasts of projected coal mining activities throughout the 208 area, an intensive investigation based on assessing mining trends, land ownership, and coal seam characteristics was conducted by GERP&DC[7]. This information was supplied to the mine waste control program in the form of energy production futures for three planning time steps (1976-80, 1981-85, and 1986-95), and in the form of an energy futures map. Projected production data was broken down into production sectors including; large surface mines, underground mines, and; potential sites of economically recoverable coal from "gob" piles. These data comprised the primary future production projections used in all of the mine waste analyses.

Data for the estimation of coal mine reclamation technologies and costs[29,30,31,32,33,34,35,36,37]** were developed from literature data as well as information provided to the project from coal mine operators within the 208 area. The reclamation options used in the analyses were decided upon during intensive discussion sessions with representatives of the largest coal mining operators in the

*Data from this source was taken to be primary information and not scrutinized for error, all other sources were used to fill-in data gaps especially 1972-1976, and cross-check selected small sectors only.

**A complete compilation of sources is presented in Volume II, Technical Report, Chapter 7.

study area.* Options used include: backfilling and blind flushing of "gob" and slurry into inactive abandoned mines; disposal of "gob" and slurry from abandoned mines through burial in active strip mines during the reclamation process; diking and conveyance of "gob" pile runoff to evaporation retention reservoirs that could be coupled with treatment facilities as necessary; and, reduction in "gob" and slurry volumes by reclamation of residual coal. Areas where each of the control options were considered to be feasible were carefully mapped and compared with the previously located underground and surface mine related pollution points. Data were then generated for each control option for each of the 269 inventoried sources ("gob", slurry and tipple sites) as to potential disposal location and haul distance. These data then formed the base input file to a reclamation cost estimation model developed for the study.**

All collected inventory and mine control data were assembled in a series of 1" = 2 mile maps based on the Illinois Department of Transportation county-highway maps. The map series provided a powerful analysis tool in that all data generated were accurately displayed on a uniform basis allowing for overlaying of one set of collected data on another. Maps generated in the series include:

1. A 1" = 2 mile base map depicting the entire Big Muddy and Saline River Basins, comprised of all or part of 14 Illinois counties
2. A rivers and streams overlay depicting all waterways throughout the area
3. A coded watershed map subdividing the entire watershed into third order catchment areas

*Meeting at the GERP&DC offices conducted in October and November, 1977.

**Details of the cost model are presented in Volume II, Technical Report, Chapter 5.

4. A map depicting the locations of all IEPA, 208 and USGS water quality and flow gaging stations in the 208 area.
5. A map indexing and locating all underground coal mining related pollution sources identified in the study.
6. A map indexing and locating known active and inactive surface mining areas and with pollution sources identified.
7. A map of the detailed watershed segmentation used as part of the computer simulation analysis.
8. A map of predicted coal development futures for the three planning time steps considered.
9. A map locating the watersheds considered in the micro-basin analysis program.
10. A map depicting areas suitable for backfilling and blind flushing as a potential control option.
11. A map depicting areas of past, present and future thick seam mining where large volume gob disposal is possible.
12. A map depicting sectors where reclaiming of "gob" from refuse piles was considered to be economically feasible.*

D. The Mine Waste Drainage Simulation Model

The Mine Waste Drainage model developed for this study is oriented toward detailed simulation of individual second order watersheds, such as Beaucoup Creek, with provisions for integrating all of the second order basins into a first order basin system. The model considers a basin, such as Crab Orchard Creek (second order basin) or Main Stem of Big Muddy (first order basin), as a network of nodes (watershed areas) and links.

*The rationale and feasibility of all control options are discussed in Chapter 8 of the Technical Report, Volume II of this series.

The nodal inflows are calculated on the basis of monthly United States Geological Survey (USGS) flow data[38] for eight gaging stations in the Big Muddy and Saline River Basins. Five stations were used to compute nodal flows in the Big Muddy and three stations were used for the Saline Basin. The subbasin inflows to each node were calculated on the basis of coefficients that translate the flows from a USGS gaging station onto the nodes. The simulation model of the Southern Illinois 208 study area routes pollutant discharges from each of the model nodes throughout the given river network. The two basins were divided into a total of 282 model nodes for the simulation analysis, with 170 in the Big Muddy and 112 in the Saline Rivers respectively.

The model defines net alkalinity and sulfate concentration for each model segment or node as a function of the land use characteristics* within the segment. An empirical relationship between net alkalinity and mining land use characteristics** was developed from water quality data collected during the 208 sampling program and local land use information. A relationship between net alkalinity as a function of the acreage of gob or slurry and mining affected area (expressed as a percentage of the nodal area) was prepared. A similar relationship was developed for predicting sulfate concentration as a function of the percent acreage of gob and slurry, affected area and farming. These relationships were then regionalized to account for the various geologic conditions encountered within the study area. The pH levels are computed in the model in terms of net alkalinity. Net alkalinity which is the difference between the acidity titrated to a pH of 8.3 and the alkalinity titrated to pH of 4.5, was chosen as the computed quality parameter since it is an accepted method

*The land use characteristics were developed by GERP&DC based on 1976 land use information.

**Mining data based on information generated by the Cooperative Wildlife Research Laboratory of Southern Illinois University updated by information from the Illinois Bureau of Mines and Minerals.

for evaluating and predicting the absence or presence of acidity. A separate empirical relationship between pH and net alkalinity was prepared for both the Big Muddy and Saline River Basins from data derived from the 208 measurement programs.* The model thus developed was calibrated using actual water quality data from the area to allow for reliable simulation of water quality in all sectors of the basins based on existing conditions. A special subprogram was developed to estimate pollutant runoff from future production as a function of production and reclamation efficiency. This procedure was coupled with the water quality simulation model to provide a powerful tool** to allow for assessments of water quality under all conditions of mining and reclamation control.

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*A detailed discussion of all aspects of the modeling approach is presented in Chapter 5 of the Technical Report, Volume II of this series.

**A "powerful tool" in this sense does not imply that the simulation model provides absolute accuracy under all conditions, as that is clearly beyond the state-of-the-art in simulation modeling efforts, especially pertaining to acid mine drainage. What is meant is that the model provides a reasonably uniform method of assessing complex interactions of varying land uses (primarily mining) as they relate to water quality within two large watershed areas.

SECTION III. ANALYSIS OF WATER QUALITY BASE-LINE CONDITIONS FOR BOTH PRESENT AND PROJECTED FUTURE MINING DEVELOPMENT

A. Overview

Analysis of estimated* water quality conditions for both present and future planning horizons are presented in this section. Four planning horizons are considered including: present conditions typifying estimated water quality levels for the base year of 1975, and the future time periods of 1975-1980, 1981-1985 and 1986-1995 reflecting projected mining impacts on water quality during these periods. Water quality results for the last year of each future period are presented.

The simulation model used in the analysis was calibrated using water quality data collected over the course of the 208 study as well as pertinent IEPA water quality data for the last several years.** Water quality conditions for the three future time steps were estimated using the simulation model with a special computational routine for adding the estimated pollutant loadings from new mining development, assuming high degrees of reclamation effectiveness pursuant to requirements of Federal Law PL 95-87.

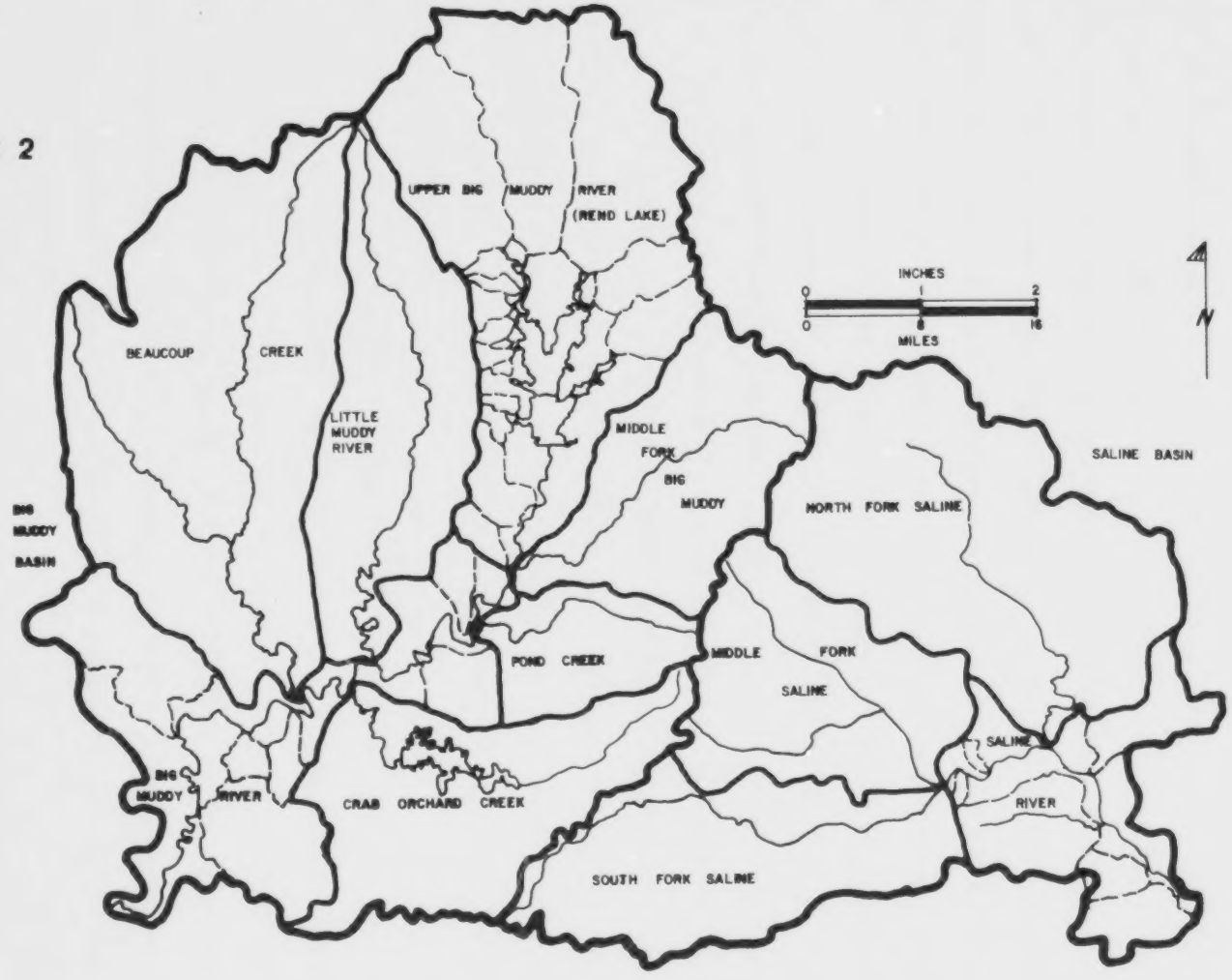
The Big Muddy River Basin was subdivided into six subbasins or second order watersheds draining into a seventh area representing the main stem of the basin. The six subbasins are as follows: Beaucoup Creek, Little Muddy River, Upper Big Muddy (Rend Lake), Middle Fork of the Big Muddy, Pond Creek, and Crab Orchard. The Saline River Basin was subdivided into three subbasins draining into a fourth area representing the main stem of the Saline River. The three subbasins of the Saline River are as follows: South Fork, Middle Fork, and North Fork. Figure 2 is a map illustrating these watersheds. Each of the eleven second order watersheds was further subdivided into smaller

*Estimated through use of the simulation model.

**Model calibration is presented in detail in Chapter 5, section of the Technical Report, Volume II of this series.

FIGURE 2

MAP OF MINE WASTE CONTROL PROGRAM AREA



drainage areas or simulation model nodes. A total of 282 model nodes were used to represent the Big Muddy (170) and the Saline (112) Basins. The number of nodes per second order basin varied from 16 for North Fork to 41 for the Middle Fork of the Saline. The actual number of nodes per basin depended upon the complexity of the river system and the extent of both present and future projected mining.

Water quality results for the environmental base-line conditions are presented for various points along the main stem and important tributaries of each of the second order watersheds. In order to provide for assessment of mine waste impacts on each of the second order watersheds, roughly 57 points of interest have been identified.* These "so-called" points of interest represent a reasonable profile of estimated water quality along each of the main stems or waterways large enough to be considered reasonable for control from a water use standpoint. The location of the discharge from a given node is defined as the point of interest.

B. Assumptions and Procedures**

Period of Hydrologic Record. Data input to the simulation model for the analyses of water quality conditions during the present and three future planning periods included 12 years of monthly average streamflow records from the eight United States Geological Survey (USGS) gages located in the study area, for the period starting in October of 1963 and ending in September of 1975. This information provided the flow base data used in the simulation model during the computation of average monthly concentrations of net alkalinity, sulfate and pH for each of the 144 calendar months at each of the 282 model node points. The results of all 144 calendar months were then summed and averaged for each of the 282 nodes and the results are presented in summary in this section and in more detail in the second volume of this report.

*Points of interest refer to simulation model nodes along certain main stem reaches throughout the study area. Results presented in this section for the points of interest are simulated results not actual measured data.

**This section provides simply an overview of the assumptions and procedures and

Water Quality Criteria. To aid in the assessment of water quality throughout the second order watersheds, the average simulated water quality results for each point of interest were ranked according to the scheme illustrated in Table 1 for the purpose of depicting sectors of predicted acceptable, marginal and critical pollutant levels for each of the four planning time steps.* Ranking criteria** for pH is given in Part A of Table 1. Acceptable pH levels (code = 0) were considered equal to or exceeding 6.5 and suitable for all uses. Marginal pH levels (code = 1) were considered to range from 5.0 up to a pH of 6.5. Critical levels (code = 2) were considered to range from 4.0 to 5.0. Finally, extremely critical levels (code = 3) were considered to be pH values less than 4.0. The relative pollutant impact for sulfates are distinguished by three levels: average values of less than 500 mg/ℓ (code = 0), falling within federal drinking water standards:*** values lying between 500 to 1500 mg/ℓ (code = 1) are considered marginally usable; and, average values exceeding 1500 mg/ℓ are considered poor. Net alkalinity levels were broken into three ranges for the Big Muddy and four ranges for the Saline Basin indicative of variations in buffering capacity. The ranges were established from examination of the pH versus net alkalinity curves developed for each basin from all data collection during the 208 monitoring programs.

Pollutant Loadings from Future Mining Activities. The projected acreages of future coal production for each of the three planning time steps were supplied by GERP&DC. Mining areas were located on the study area base map and acreages per model node were then established for each time step. Levels of coal production per year for each time step were then estimated

is by no means comprehensive. A detailed presentation may be found in Chapter 5 of the Technical Report, Volume II of this series.

*Time steps and periods are used interchangeably in this report.

**All ranking criteria used in this report are simply a judgmental scheme developed by the consultants as a means of simplifying the effort required in making comparisons. The steps so defined are not intended to reflect any legal or regulatory mandate or standard.

***Simply used as a reference point.

TABLE 1

CRITERIA FOR RANKING WATER QUALITY RESULTS

A.	pH	
Range	Level	Ranking
> 6.5	0*	Acceptable
≥ 5.0 - 6.5	1	Marginal
4.0 - 5.0	2	Critical
≤ 4.0	3	Very Critical
B.	Sulfate (mg/ℓ)	
≤ 500	0	Acceptable
> 500 - 1500	1	Marginal
> 1500	2	Poor
C.	Net Alkalinity (mg/ℓ) **	
Big Muddy		
> + 75.	0	Adequate Buffering Capacity
0 to + 75.	1	Limited Buffering Capacity
< 0	2	No Buffering Capacity (Critical)
Saline		
> 100	0	Adequate Buffering Capacity
> + 10 - 100	1	Limited Buffering Capacity
- 150 to + 10.	2	No Buffering Capacity (Critical)
< - 150.	3	Acidic Conditions

*Numbers are level code.

**It was necessary to use an additional ranking cell for net alkalinity in the Saline Basin due to the slope of the pH versus net alkalinity curve generated from the actual monitoring data for the basin. Within the defined range -150 to 100 mg/ small NA changes cause rapid pH deflection.

using historical production patterns for surface and underground mining activities within the 208 study area. Average sulfate and net alkalinity generation levels per acre of mining operation under present regulations, were estimated per node using literature results tempered by the results of the 208 measurement program. Literature data was then used to generate reclamation pollutant reduction efficiency curves per year subsequent to initiation of reclamation. These curves were adjusted to reflect recent reclamation experiences in both the Big Muddy and Saline Basins. These data were then input into the special routine for estimating the pollutant levels as a function of time.* The resultant additive** loadings for the last year of each planning time step for each of the nodes impacted by mining development were then used as data inputs to the water quality simulation model for estimating future water quality conditions.

C. Present and Future Assessments of Water Quality Conditions in the Big Muddy Basin

This sub section presents the results of the water quality simulations for the Big Muddy Basin by second order watershed. The analysis focuses on the points of interest within each subbasin that were previously described. Locational descriptions of the points of interest are presented in tabular form in the assessments for each subbasin. These locations are further indentified on subbasin maps showing the nodes used in the simulation model. The projected mean water quality conditions for net alkalinity, pH and sulfate are depicted in graphical form using the numerical water quality ranking indicies earlier described in Part B of this section. This information is shown beside the maps for each subbasin.

Beaucoup Creek. The descriptions of 10 interest points in the Beaucoup Creek subbasin are given in Table 2. Each site in the table is

*Detailed explanation may be found in Chapter 5 of the Technical Report, Volume II of this series.

**Additive to the base-line or 1976 conditions.

TABLE 2

LOCATIONAL DESCRIPTION OF WATER QUALITY INTEREST POINTS

BEAUCOUP CREEK, BIG MUDDY RIVER BASIN

Map Number	County	Description
5	Perry	Main Stem of Beaucoup Creek North edge of Pinckneyville.
8	Perry	Main Stem of Beaucoup Creek 2.5 miles Southeast of Pinckneyville.
11	Perry	Main Stem of Beaucoup Creek, 4 miles East of Pyramid State Park just South of Rt. 152.
16	Perry	Upper Gallum Creek, 2 miles Northeast of Cutter.
18	Perry	Gallum Creek, 2 miles West of Pyramid State Park, North of Rt. 4
23	Perry	Gallum Creek, 4 miles South of Pyramid State Park, between Little Gallum Creek & Pipestone Creek.
24	Jackson	Confluence of Lower Gallum Creek and Beaucoup Creek.
29	Jackson	Confluence of Rattlesnake Creek and Beaucoup Creek, 2 miles Southwest of Verginnes.
34	Jackson	Beaucoup Creek, 4 miles Northwest of Desoto.
36	Jackson	Beaucoup Creek, just Upstream of Confluence of Big Muddy River.

described by a map reference number, the county in which the site is located within and a short locational description. These locations can be identified on the subbasin map shown in Figure 3. All of these sites are situated on the main stem of Beaucoup Creek with the exception of locations 16, 18 and 23 which are within the Gallum Creek watershed. Little mining has occurred in the northern portion of the basin and very little production is projected in the future. Considerable coal production activities have occurred in the lower half of the basin, particularly the area within Perry County. Heavy surface mining in this area is projected for all future time steps.

There are several fundamental geological/water quality phenomena impacting the analysis of present and especially projected future conditions within the watershed. First of all, there are vast deposits of strippable thick seams of coal overlayed by vast layers of limestone. In the surface mining process the limestone layer is mixed with the spoil, effectively bringing large amounts of limestone to the surface. This limestone will then act as a long-term natural source of neutralization for any acid mine drainage production and more importantly, through the neutralization and leaching process. This factor is of extreme importance in this basin and all subbasins within the northern half of the Big Muddy Basin having similar limestone characteristics. Therefore, any large scale surface mining activities conducted in this areas have the potential for producing an uncontrollable* sulfates problem even with the highest degree of modern reclamation being practiced.** Analyses of persent water quality measurements collected both by IEPA and the 208 program confirm this point.

*Uncontrollable in this sense means that there are no economically feasible technologies available for controlling the substance.

**Sulfates are produced in the neutralization process from the reaction of sulfuric acid with the lime (calcium carbonate) producing gypsum or calcium sulfate. High concentrations of calcium sulfate can be found in areas impacted by AMD that is subsequently neutralized by lime.

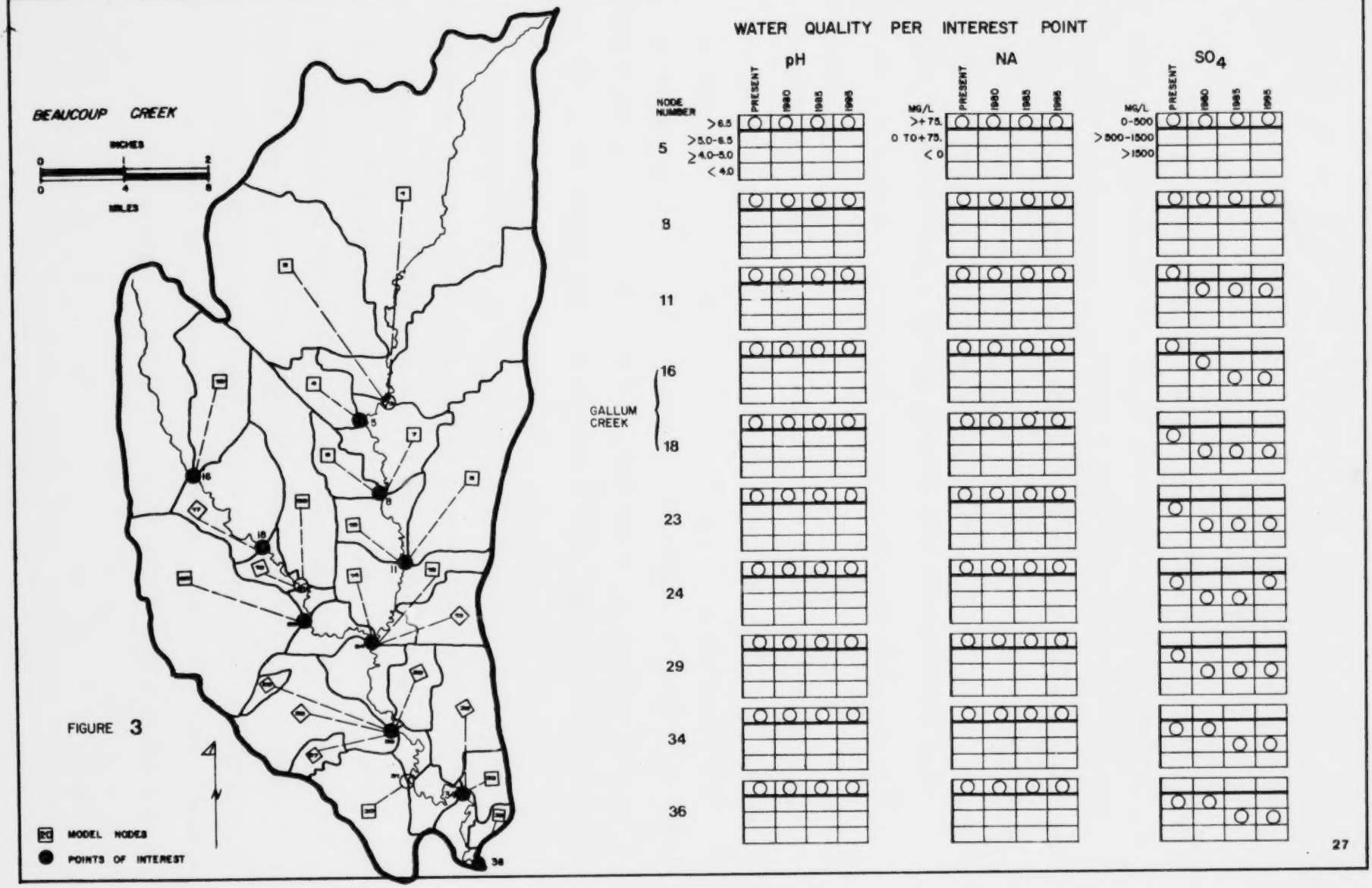

BEAUCOUP CREEK
INCHES
0
2
0
4
6
MILES
MODEL NODES
POINTS OF INTEREST
WATER QUALITY PER INTEREST POINT
pH
NA
SO4
PRESENT
1980
1985
1995
NODE NUMBER
>6.5
>5.0-6.5
≥4.0-5.0
<4.0
MG/L
>+75.
0 TO+75.
<0
0-500
>500-1500
>1500
5
8
11
16
GALLUM CREEK
18
23
24
29
34
36

FIGURE 3

Ranked values for projected average pH, net alkalinity and sulfate concentrations in the Beaucoup Creek subbasin are graphically indicated for each point of interest on the right hand side of Figure 3. The results indicate that the water quality levels in the upper reaches of Beaucoup Creek, that is, at locations 5 and 8, are presently at acceptable levels and will continue at favorable levels during the entire future period considered. Projected future coal development in the area between location 8 and 11, is estimated to result in increased sulfate levels beyond 500 mg/ℓ for each of the future time steps. Net alkalinity and pH are estimated to remain at acceptable levels.

The sulfate levels in the upper Gallum Creek catchment area, location 16, are presently below 500 mg/ℓ and are estimated to rise due to projected increased mining activities to level 1 (500 - 1500 mg/ℓ) in 1980 and thereafter are estimated to increase up to level 2 (above 1500 mg/ℓ) throughout the balance of the future time steps. Net alkalinity concentrations and pH are estimated to continue at acceptable levels within this sector.

The pH and net alkalinity levels in the lower portion of Gallum Creek, locations 18 and 23, are estimated to remain at acceptable levels. Projected increases in mining production in this area are estimated to result in a sulfate rise from level 1 for present conditions up to level 2 for all future time steps. Sulfate levels in the lower portion of Beaucoup Creek (locations 24 through 36) are presently between 500 - 1500 mg/ℓ and are estimated to exceed 1500 mg/ℓ during the second planning time step. In summary, under present conditions the water quality levels are at acceptable

levels in the Beaucoup subbasin with the exception of marginal sulfate levels in Gallum Creek and in the lower reaches of Beaucoup Creek. Projected mining impacts in the future are estimated to result in considerable sulfate increases in these areas. Net alkalinity and pH are estimated to remain at acceptable levels. These conclusions are reflective of conditions that would occur if no control was imposed upon past existing sources.

Little Muddy River. Descriptions of six locations along the Little Muddy River are given in tabular form in Table 3. These locations can be identified on the basin map contained within Figure 4. A minor degree of mining has occurred in the lower half of this subbasin resulting in existing low level of pollutant emissions. Extensive mining in the future is projected to occur in the lower portions of the subbasin.

Net alkalinity and pH are presently at acceptable levels and are estimated to remain acceptable for the entirety of the future planning period. The present average sulfate levels lie between 500 - 1500 mg/ℓ for portions of the upper basin, that is, at location 15, and for all of the lower basin. These levels are expected to continue through 1980 but are estimated to exceed 1500 mg/ℓ at locations 16 and 27 in 1985. In the final planning time step, the sulfate levels are estimated to exceed 1500 mg/ℓ at locations 15, 24 and 27.

In summary, pH and net alkalinity are estimated to be at acceptable levels for the entire planning period. Projected mining impacts are estimated to raise the present sulfate concentrations already considered marginal in this analysis, up to levels exceeding 1500 mg/ℓ.

Upper Big Muddy, Rend Lake Area. The descriptions of three points of interest considered in the Upper Big Muddy River subbasin are given in

TABLE 3

LOCATIONAL DESCRIPTION OF WATER QUALITY INTEREST POINTS
LITTLE MUDDY R VER, BIG MUDDY RIVER BASIN

Map Number	County	Description
8	County Line Perry	Confluence of Hog Creek and Little Muddy River.
15	Perry	Confluence of Blacksop Creek and Reese Creek, 3 miles East of DuQuoin.
16	County Line Perry	Confluence of Reese Creek and Little Muddy River.
20	Jackson	Confluence of Six Mile Creek and Little Muddy River, 1½ miles East of Elkville.
24	Jackson	Little Muddy River, Midway between Elkville and Desoto.
27	Jackson	Little Muddy River, just North of Confluence with Big Muddy River.

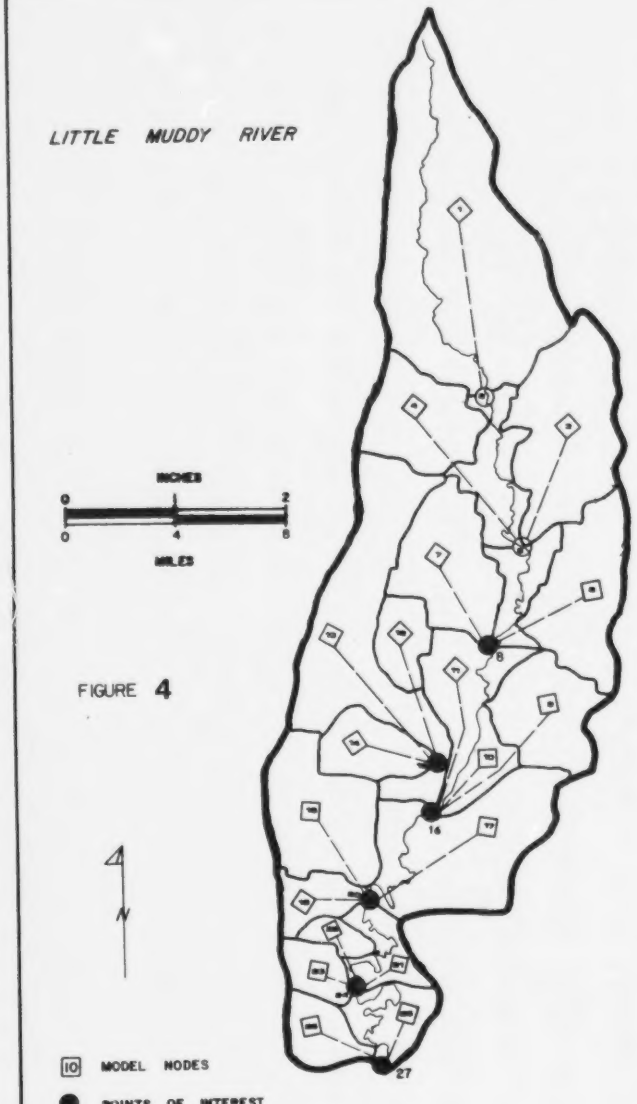


FIGURE 4

WATER QUALITY PER INTEREST POINT

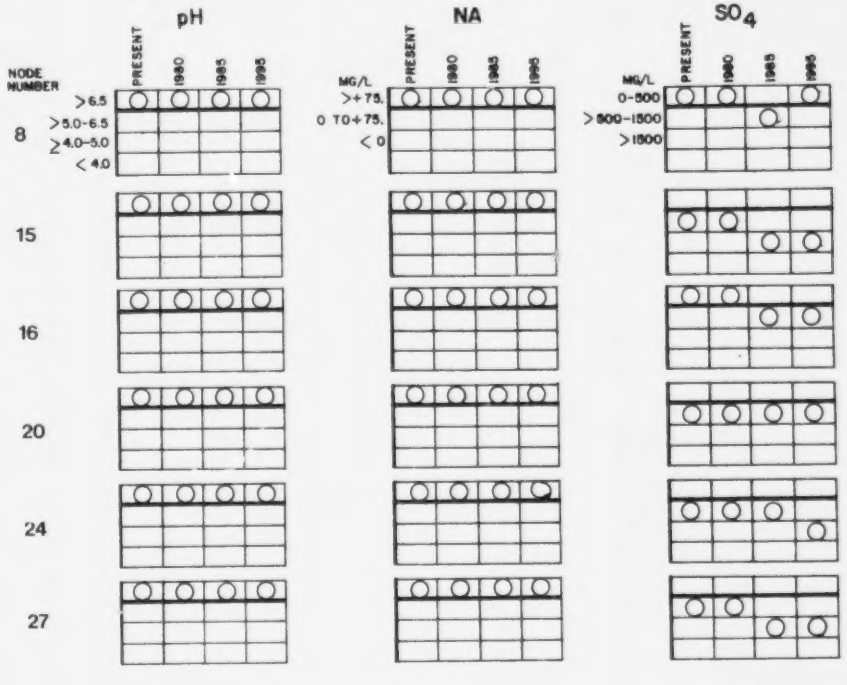


Table 4. These locations can be identified from the subbasin map shown in Figure 5. Old abandoned underground mines in the tributary drainage area to the west of the lake are represented by node 9. The outlet of Rend Lake is noted by node 18. Projections of future coal mining indicate no further activity in this subbasin. Simulation model results of water quality at node 9 indicate pH levels less than 4.0 resulting from drainage from old underground mining activities. Net alkalinity concentration of this drainage is very low. Sulfate levels lie between 500 to 1500 mg/ℓ. Water quality levels of the Rend Lake discharge at location 18 are all acceptable. It is interesting to note that the average pH and net alkalinity concentrations determined from both the simulation analysis and field data collected in the 208 measurement program, show that these levels are somewhat lower than would be expected from a large surface body of water, but still acceptable at this time. Any future mining development in the watershed may tip the net alkalinity balance and result in depressed pH conditions because the buffering capacity of the lake, indicated by the low positive net alkalinity levels, would be rapidly depleted if additional acid drainage were discharged to the lake.

Middle Fork of Big Muddy River Basin. The descriptions of four points of interest along the main stem of the Middle Fork are given in Table 5 with the points of interest identified in the subbasin maps shown in Figure 6. Very little mining activitity has occurred in the past in this subbasin and only minor activities are projected in the future.

Water quality levels in this subbasin are presently acceptable and are projected to be within the acceptable range in the future.

Pond Creek, Big Muddy River Basin. The descriptions of six points along Pond Creek are given in Table 6 with the locations being identified in

TABLE 4

LOCATIONAL DESCRIPTION OF WATER QUALITY INTEREST POINTS
UPPER BIG MUDDY RIVER, REND LAKE

Map Number	County	Description
9	Franklin & Hamilton	Area West of Rend Lake Tributary o Lake
18	Franklin	Outlet to Rend Lake
23	Franklin	Upper Big Muddy River just upstream of Confluence with Middle Fork

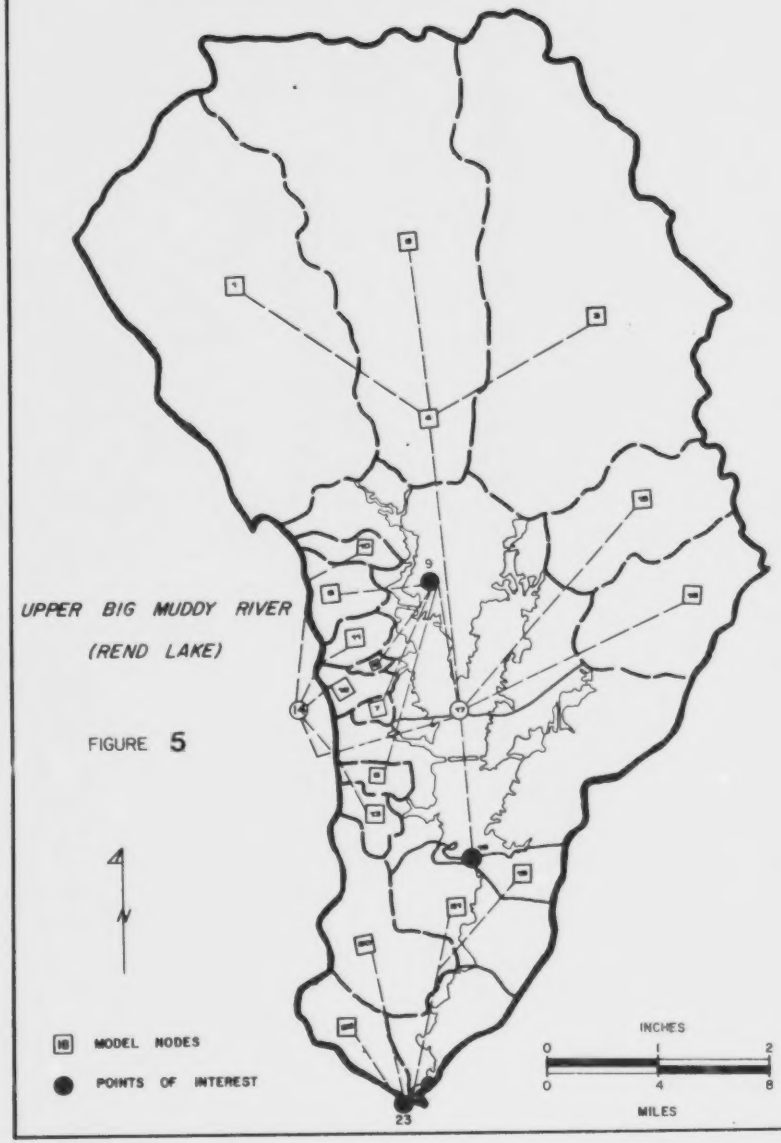

UPPER BIG MUDDY RIVER
(REND LAKE)
MODEL NODES
POINTS OF INTEREST
INCHES
0 1 2
0 4 8
MILES

FIGURE 5

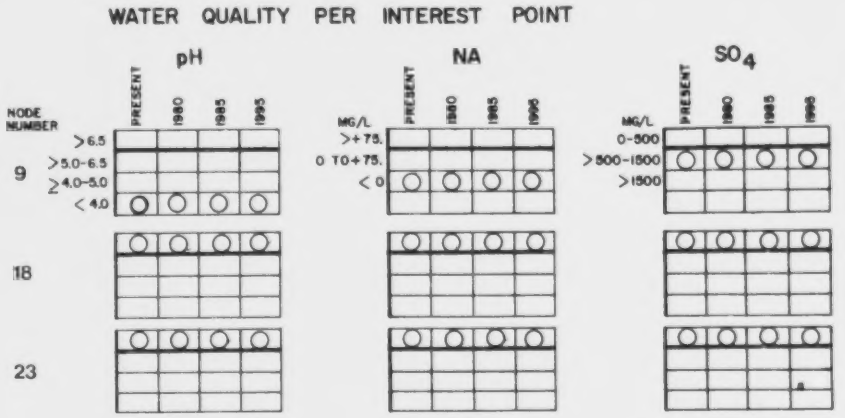

WATER QUALITY PER INTEREST POINT
pH
NA
SO4
NODE NUMBER
PRESENT
1980
1985
1995
>6.5
>5.0-6.5
>4.0-5.0
<4.0
MG/L
>+75.
0 TO+75.
<0
0-500
>500-1500
>1500
9
18
23

TABLE 5

LOCATIONAL DESCRIPTION OF WATER QUALITY INTEREST POINTS
MIDDLE FORK, BIG MUDDY RIVER

Map Number	County	Description
6	Franklin	Middle Fork, 1 mile Southeast of Steel City.
10	Franklin	Middle Fork, 2 miles South of Benton.
14	Franklin	Middle Fork, 1 mile North of West Frankfort.
18	Franklin	Middle Fork, just Upstream of Confluence with Big Muddy River.

MIDDLE FORK BIG MUDDY

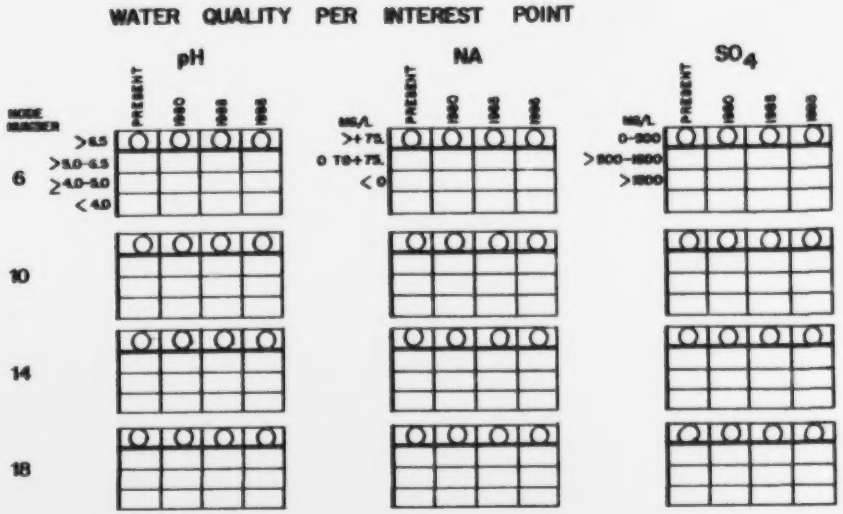
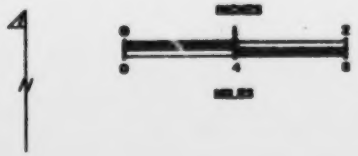


FIGURE 6



3 MODEL NODES

POINTS OF INTEREST

TABLE 6

LOCATIONAL DESCRIPTION OF WATER QUALITY INTEREST POINTS
POND CREEK, BIG MUDDY RIVER BASIN

Map Number	County	Description
3	Franklin	Pond Creek, 3 miles Southeast of West Frankfort.
6	Franklin	Pond Creek, 1/2 mile due South of West Frankfort.
9	Williamson	Pond Creek, 2 miles East of Freeman Spur.
13	Williamson	Pond Creek, just Upstream of Confluence of Lake Creek and Pond Creek.
17	Williamson	Pond Creek, 1 mile Southwest of Freeman Spur.
19	Williamson	Pond Creek, just Upstream of Confluence with Big Muddy River.

the subbasin map shown in Figure 7. This watershed is presently heavily impacted by mining activities and considerable future development is projected to occur in the final planning time period of 1986-1995.

Water quality levels of the upper reaches of Pond Creek are good and will continue in the future. pH as well as the net alkalinity concentration in the lower reaches of Pond Creek are presently acceptable and are projected to degrade slightly in the final planning step. Sulfate levels in the lower portion of the area are marginal for present conditions and are estimated to increase beyond 1500 mg/ℓ during the third planning period.

Crab Orchard Creek. Descriptions of six interest points in the Crab Orchard subbasin are given in Table 7 and identified on the subbasin map contained within Figure 8. Water quality conditions of the drainage from the upper watershed of Crab Orchard Creek are considered at location 4. The catchment area upstream of this point contains numerous old abandoned gob, slurry and refuse areas. Crab Orchard Lake outlet is at location 14. Significant future coal mining activities are projected to occur in the upper Crab Orchard watershed during the second and third planning time steps.

Water quality levels at node 4 are at marginal levels for all three parameters reflecting the acidic drainage from old mining activities. Future coal mining activities are projected to further degrade water quality at this location. Concentrations of net alkalinity for this location are estimated to depress yielding a lowered pH, to below acceptable levels. Sulfate concentrations are estimated to increase from present levels considered marginal in this analysis, up to concentrations exceeding 1500 mg/ℓ.

Water quality levels in the Crab Orchard Lake outlet are presently acceptable. It is estimated, however, that sulfate concentrations in the

TABLE 7

LOCATIONAL DESCRIPTION OF WATER QUALITY INTEREST POINTS
CRAB ORCHARD CREEK, BIG MUDDY RIVER BASIN

Map Number	County	Description
4	Williamson	Main Stem of Crab Orchard Creek, 0.5 miles East of Marion.
9	Williamson	Upstream End of Crab Orchard Lake.
14	Williamson	Outlet of Crab Orchard Lake.
18	Williamson	Confluence of Drury Creek and Crab Orchard Creek.
21	Williamson	Crab Orchard Creek, just upstream of Confluence with Big Muddy River.

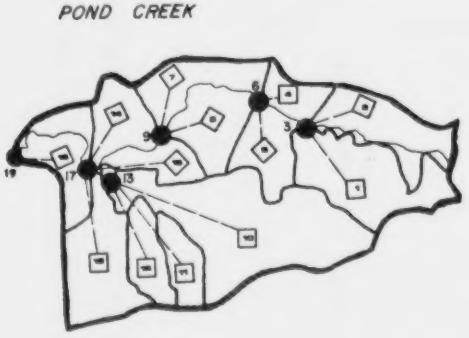
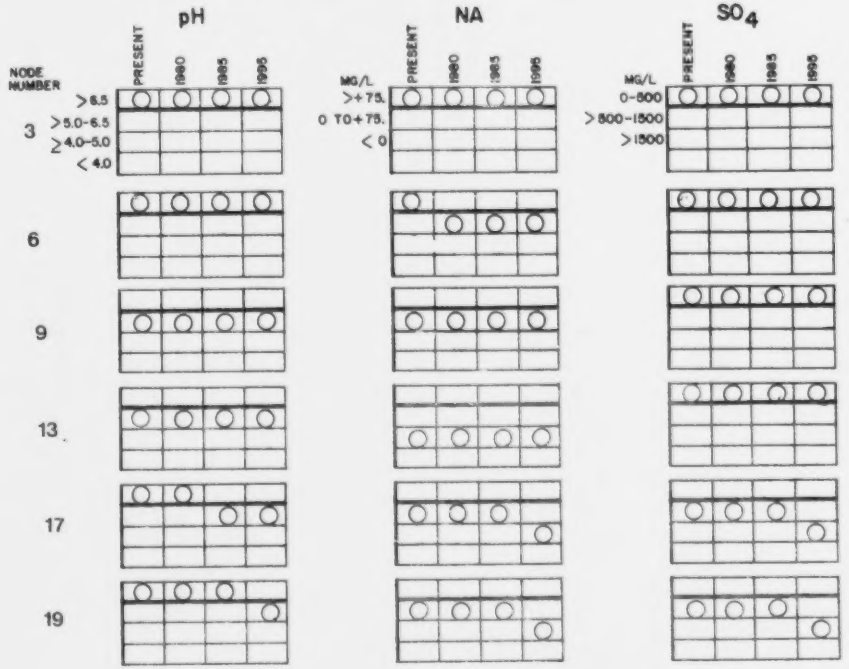


FIGURE 7

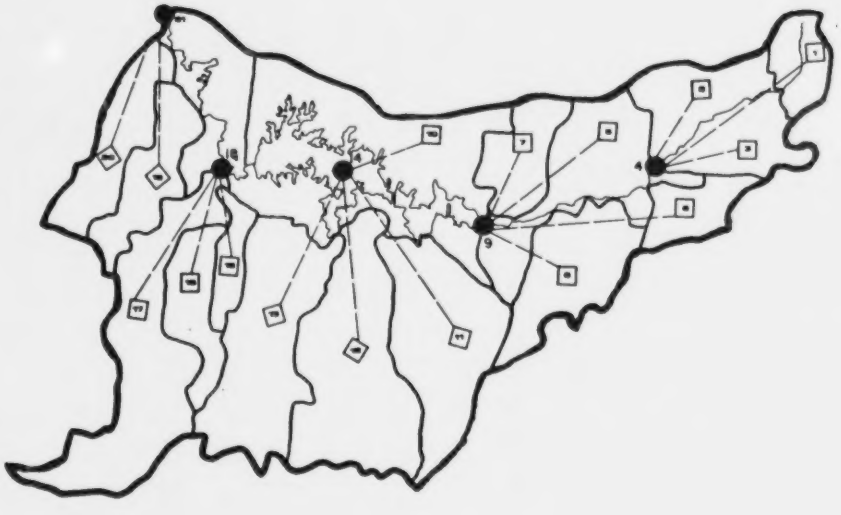
[14] MODEL NODES

● POINTS OF INTEREST

WATER QUALITY PER INTEREST POINT



CRAB ORCHARD CREEK



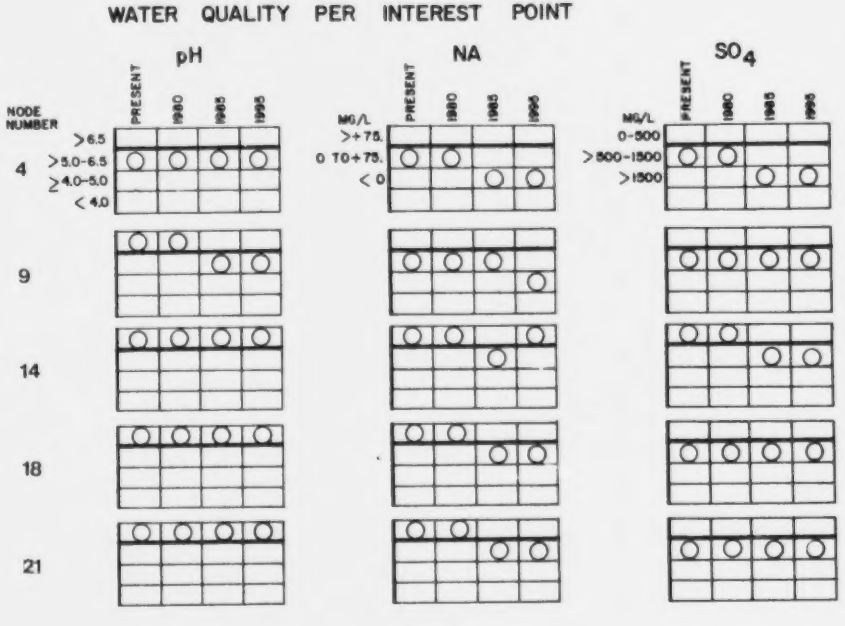


FIGURE 8

17 MODEL NODES

POINTS OF INTEREST

lake will rise above 500 mg/ℓ during the second and third planning time steps. Net alkalinity concentrations during these periods will depress to levels considered limited in buffering capacity for any further acidic drainage. Although the natural buffering capacity of the lake may reduce the additional acidic inputs from the projected future mining activities, it is doubtful that the sulfate levels would depress down to acceptable drinking water limits. Control of the existing mine wastes sources in the upper watershed is therefore important from the standpoint of protecting the lake waters that could be used as a potential water supply.

Water quality conditions at the confluence of Drury and Crab Orchard Creeks, location 18, are estimated to be acceptable with the exception of sulfates which presently exceed 500 mg/ℓ. Net alkalinity levels primarily due to loadings from the Sycamore Creek watershed are estimated to depress thereby lowering the buffering capacity for neturalizing additional acidic inputs.

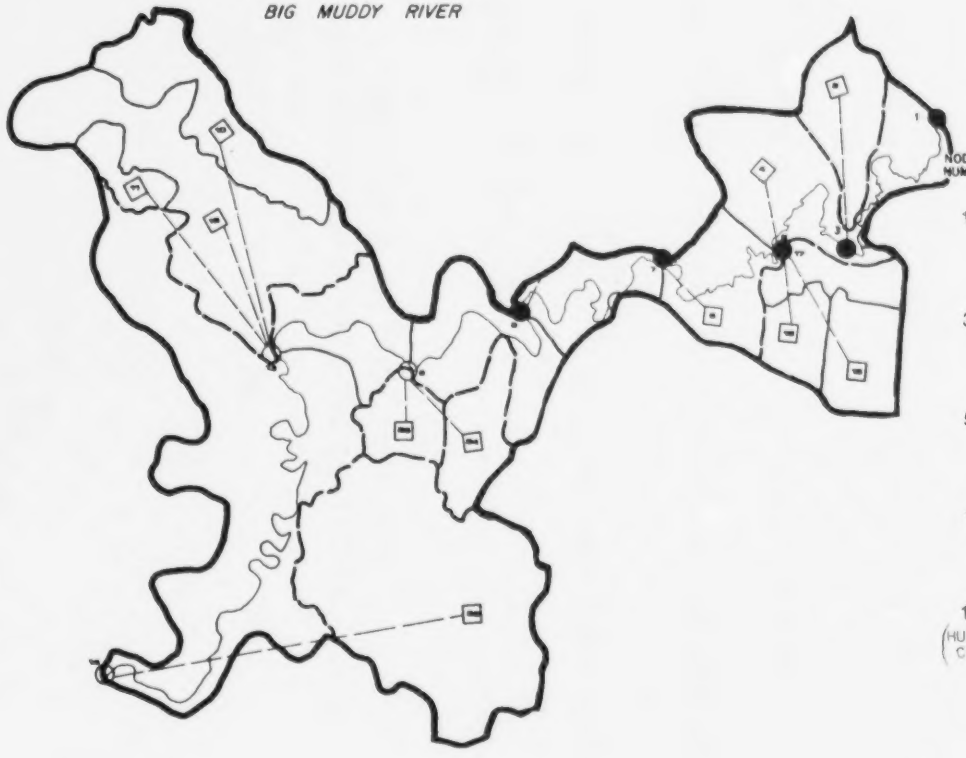
In summary, the headwaters of Crab Orchard Creek are somewhat impacted by old mining activities and water quality are estimated to further degrade from projected mining activities in the second and third planning time steps. Water quality in Crab Orchard Lake, is presently good but is estimated to degrade somewhat as a result of increased mining in the upper catchment areas.

Main Stem of the Big Muddy River. Descriptions of five interest points in the main stem of the Big Muddy are given in Table 8 with the points being located on Figure 9. Location 17 is at the confluence of

TABLE 8

LOCATIONAL DESCRIPTION OF WATER QUALITY INTEREST POINTS
MAIN STEM OF BIG MUDDY RIVER BASIN

Map Number	County	Description
1	Franklin	Confluence of Upper Big Muddy River, Middle Fork and Big Muddy River.
3	Williamson	Confluence of Pond Creek and Big Muddy River.
5	Williamson	Confluence of Little Muddy River and Big Muddy River.
7	Williamson	Confluence of Little Muddy River and Big Muddy River.
17	Williamson	Outlet of Hurricane Creek.



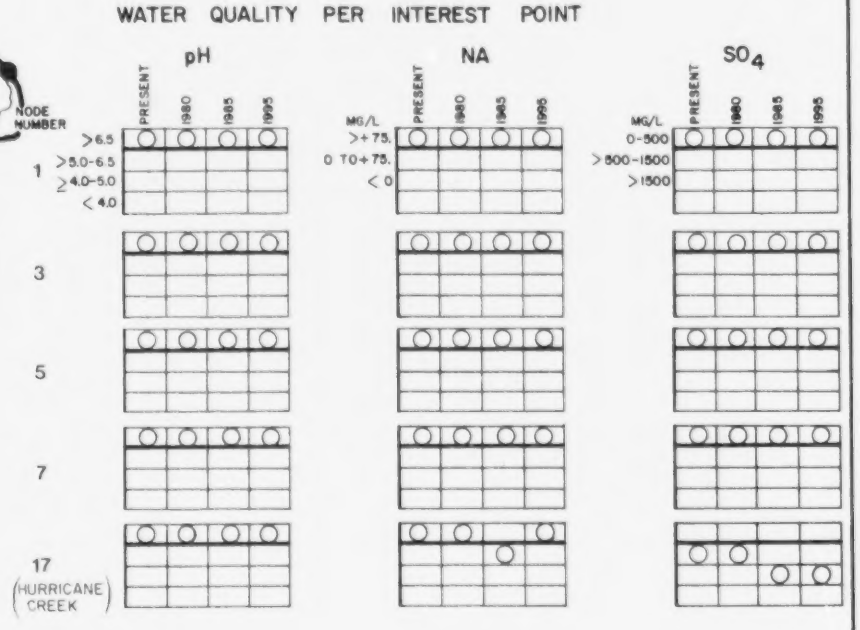
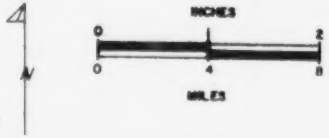


FIGURE 9

[3] MODEL NODES

POINTS OF INTEREST



Hurricane Creek. Water quality levels along the Main Stem of the Big Muddy are at acceptable levels and are estimated to remain in this condition throughout the entire planning period considered. Sulfate concentrations at the outlet of Hurricane Creek presently exceed 500 mg/ℓ. Future mining activities are projected in this area during the latter two planning time steps. Sulfate concentrations in the area are estimated to rise significantly to levels over 1500 mg/ℓ.

D. Summary of Water Quality Assessments in the Big Muddy River Basin

Water quality throughout the Big Muddy Basin presently is generally good with only a few catchment areas exhibiting problems. The Gallum Creek area located in the northwest portion of the Beaucoup Creek watershed presently exhibits high sulfate concentrations. Portions of the lower Pond Creek subbasin are presently impacted by mining activities resulting in depressed pH levels and high sulfate concentrations. Waters in the upper portion of the Crab Orchard Creek watershed exhibit slightly acidic conditions and high sulfate levels due to runoff from abandoned mining refuse. With the exception of small isolated pollution pockets interspersed throughout the watershed, especially along the western shore of Rend Lake, water quality throughout the Big Muddy Basin may be considered acceptable with respect to the parameters considered in this analysis. Future water quality projections indicate a potential for an uncontrollable sulfates problem in varying degrees throughout most of the Big Muddy Basin including: Beaucoup, Pond, and Crab Orchard Creeks as well as the Little Muddy River due to neutralization of acid mine runoff from increased surface mining activities. Acidic drainage problems are estimated to occur in the lower Pond and upper Crab Orchard Creek watersheds as a result of projected

increased mining activities. These conclusions are based on the premise that no reclamation control of existing mining related pollution problems will be conducted.* The next section presents analysis of and control programs and costs for minimizing the overall water quality impact of mine drainage pollution from past, present and future projected activties.

E. Present and Future Assessments of Water Quality Conditions in the Saline River Basin

This subsection presents the results of the water quality simulation for the Saline River Basin per second order watershed. The analysis focuses on a number of points of interest within each subbasin, generally along the main stem of each sub-system.

South Fork of the Saline River. Descriptions of six points of interest along the South Fork are given in Table 9 and can be located in the subbasin map shown in Figure 10. The South Fork of the Saline has been historically the most heavily mine waste impacted stream in the entire 208 study area. Vast quantities of "gob," slurry, refuse and spoil are strewn throughout the watershed from old abandoned mining operations. The problem is further compounded by the acid nature of the spoil making any mining activity potentially highly polluting. Although much of the available coal within the South Fork watershed has been already mined, continued activities are projected for the first and third planning time step.

Water quality at location 8 situated in the headwaters of the catchment area is generally good with only sulfate concentrations exceeding 500 mg/ℓ. There is little mine impacted area up to this point and much of the area is presently used for farming. The relatively high sulfate concentrations found in this sector are most probably due to washoff of

*Existing as of 1976. Certainly some of the past abandoned problems will be reclaimed under future mining activities, thereby reducing the baseline water quality problems to a degree. Since future coal mining developments are considered to be propriatory information by the coal companies and were specifically withheld from the 208 study, it was impossible to estimate the reduction in old problems that will occur due to future activities and was therefore not considered in this analysis.

TABLE 9

LOCATIONAL DESCRIPTION OF WATER QUALITY INTEREST POINTS
SOUTH FORK, SALINE RIVER BASIN

Map Number	County	Description
8	Saline	South Fork, Midway Between Pittsburg and Stonefort, 1½ miles Northwest of Pal 38 Project.
11	Saline	Confluence of South Fork and Sugar Creek.
16	Saline	Confluence of Pond Creek and South Fork.
19	Saline	Confluence of Little Saline River and South Fork, 1½ miles Southeast of Carrier Mills.
24	Saline	South Fork at Route 145.
31	Saline	South Fork, just Upstream of Confluence with Middle Fork.

SOUTH FORK SALINE

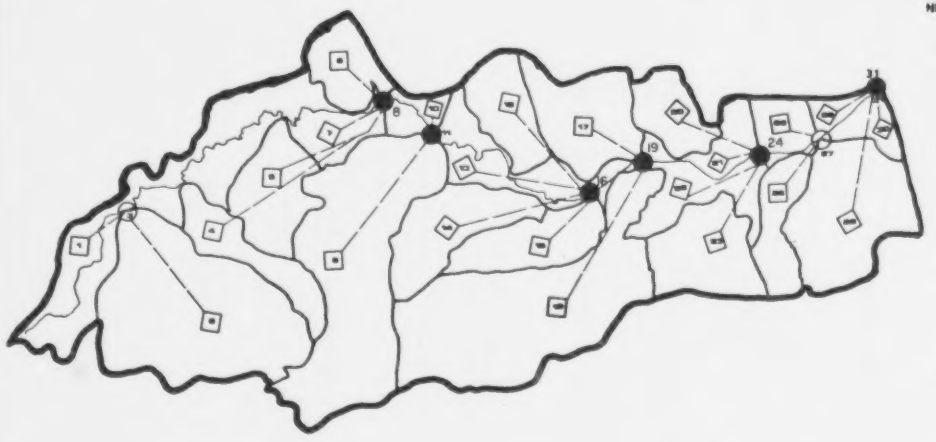
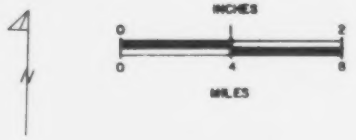


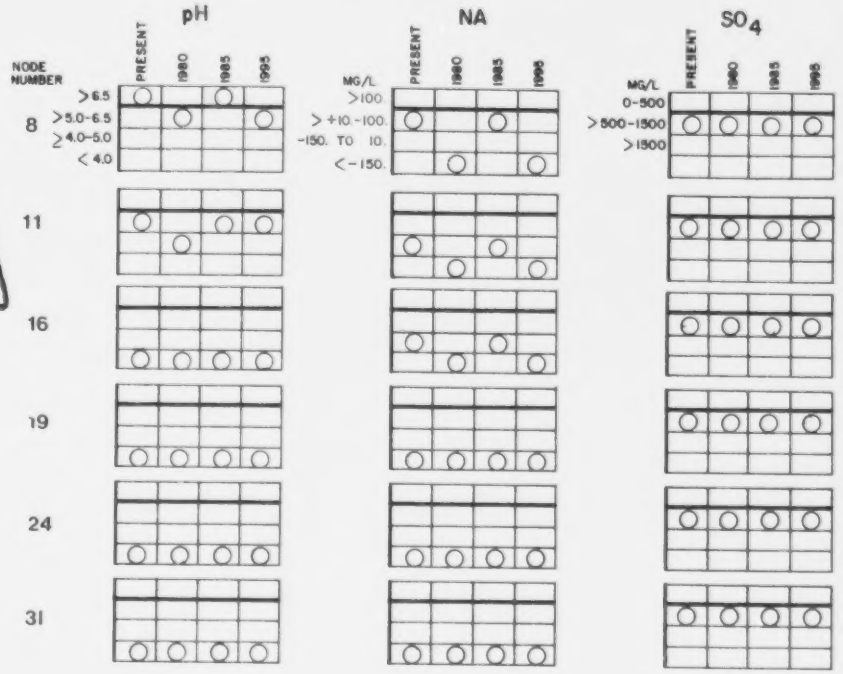
FIGURE 10



21 MODEL NODES

POINTS OF INTEREST

WATER QUALITY PER INTEREST POINT



agricultural lime from farmed areas.* Water quality conditions throughout the sector are predicted to deteriorate during the first and third planning time steps. The pH levels are estimated to decrease below the acceptable range during these periods. Net alkalinity is estimated to decrease to near zero thus resulting in no further buffering capacity for neutralizing additional acidic pollutants.

Water quality at location 11 where Sugar Creek enters the South Fork is presently well below acceptable levels and is projected to degrade even further to critical levels during the first planning time step. It is estimated that the resultant pH will lie between 4.0 and 5.0. Water quality conditions are estimated to improve slightly in the second period only to deteriorate in the final planning time step.

Water quality conditions at all downstream locations in the basin are presently at very critical levels and are estimated to remain so throughout the entire planning time period considered. Presently no fish and a severely depressed diversity of other aquatic life exist within the watershed. The sulfate levels are estimated to remain at marginal levels not increasing dramatically in the future over the entire basin.

In summary, the South Fork of the Saline is severely polluted from past and to a minor extent, present mining activities rendering it to be effectively a dead water body.** Future projections indicate that the present situation will only get worse with increased mining in the watershed.

Middle Fork of the Saline River. Decriptions of seven points of interest for the Middle Fork are given in Table 10 and can be identified in the subbasin map shown in Figure 11. This subbasin contains vast quantities

*This is not to state that the lime contains sulfates. It is most probable that the lime reaction with the acid overburden following the previously described neutralization process is responsible for the sulfate production in the area.

**Dead with respect to recreational fish life and similar aquatic species.

TABLE 10

LOCATIONAL DESCRIPTION OF WATER QUALITY INTEREST POINTS
MIDDLE FORK OF SALINE RIVER BASIN

Map Number	County	Description
6	Williamson	Bankston Fork of Middle Fork, ½ mile South of Route 13.
9	Saline	Bankston Fork of Middle Fork, ½ mile South of Rt. 13, 5½ miles West of Harrisburg.
18	Saline	Bankston Fork of Middle Fork, just South of Rt. 13, 3½ miles West of Harrisburg.
22	Saline	Confluence of Brushy Fork and Bankston Fork.
31	Saline	Confluence of Bankston Fork and Middle Fork.
38	Saline	Middle Fork, 2 miles East of Harrisburg.
41	Saline	Middle Fork, just Upstream of Confluence with South Fork.

MIDDLE FORK SALINE

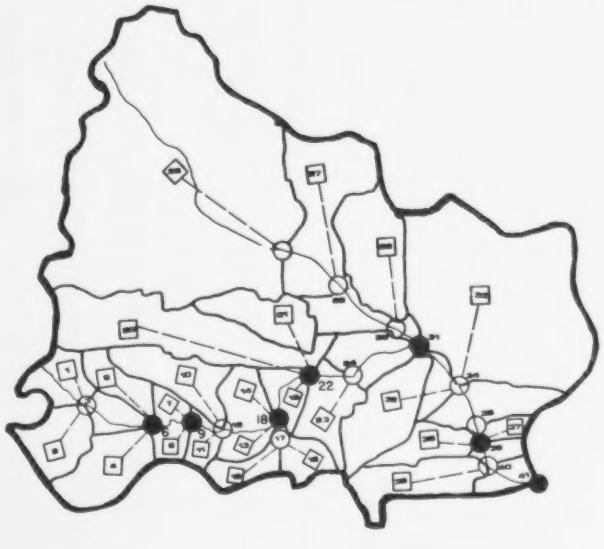
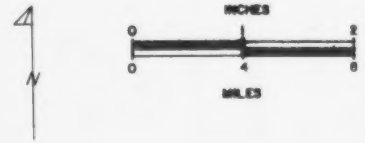


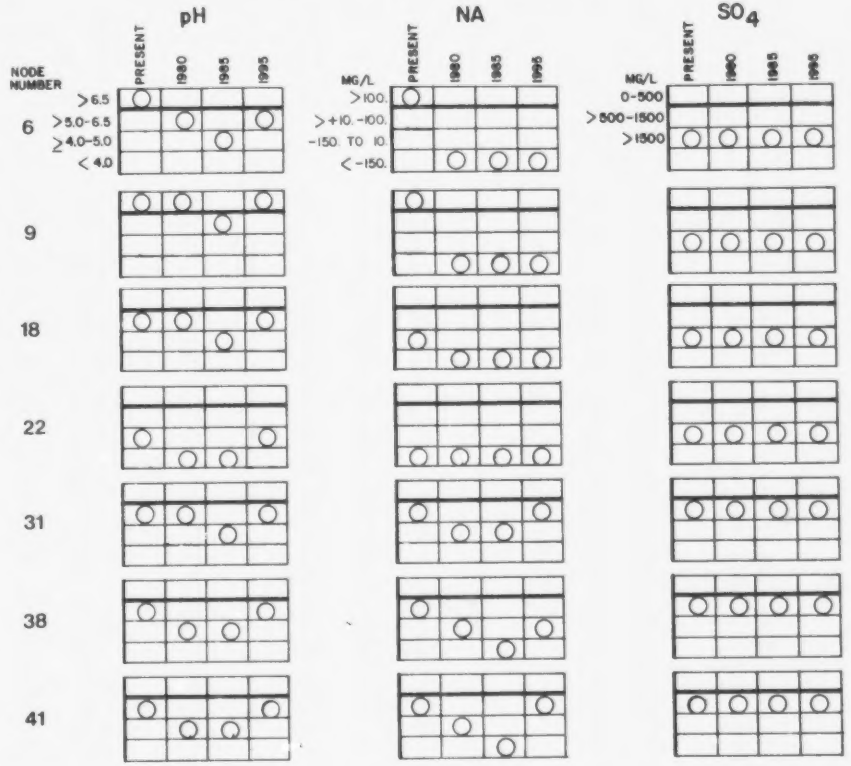
FIGURE **11**



[21] MODEL NODES

● POINTS OF INTEREST

WATER QUALITY PER INTEREST POINT



old "gob," slurry and refuse piles scattered predominantly in the lower portion of the catchment area. Extensive new coal mining production is projected to occur throughout this subbasin during the entire planning period considered.

Water quality levels in the upper reaches of Bankston Fork are presently good with the exception of sulfate levels exceeding 1500 mg/ℓ. These levels are estimated to further increase during the first planning time step and are estimated to rise markedly occurring during the second period. Net alkalinity concentrations are estimated to plummet to critical levels.* Projected future mining activities are predicted to cause severe degradation of acceptable water quality conditions.

Water quality levels in the lower portion of Bankston Fork, that is, at location 22 presently are at critical levels for all parameters and are estimated to degrade even further in future time steps due to future mining activities.

Water quality in the Middle Fork downstream of the confluence with Bankston Fork are presently near marginal levels for all parameters. Projected future mining activities in the Bankston Fork watershed as well as in the lower portions of the Middle Fork catchment area are estimated to decrease water quality to critical levels during the second planning time step. These levels are estimated to slightly improve during the third planning period as the projected mining production diminishes.

In summary, the water quality levels in the Middle Fork presently are generally good with the exception of the extreme lower portion of Bankston Fork

*The standard deviation of the simulated pH values for future conditions exceeded 1.8 units implying that lower pH values than those indicated in Figure 11 could frequently occur.

Projected future mining in the area is estimated to cause drastic degredation in water quality in the future.

North Fork of the Saline River. The North Fork of the Saline River is depicted on the map shown in Figure 12. Location 16* at the outlet of the subbasin is considered to be the sole point of interest since little past, present or future mining is projected for the area. Insignificant mining has occurred in the past in this subbasin and the area is predominently used for farming. Future mining activities are projected to occur in the lower portion of the area during the second planning time step. Water quality concentrations at this location are presently acceptable and are estimated to remain in this condition throughout the entire planning period considered. Net alkalinity concentrations are estimated to depress to marginal levels during the second time step due to projected mining. This area serves as a good background sector in the Saline River Basin. Without mining, the area's water quality is quite good.

Main Stem of the Saline River Basin. Descriptions of five points of interest for the Main Stem of the Saline River are given in Table 11 and are identified on the subbasin map shown on Figure 13. These locations are situated at confluence points of various rivers and creeks along the Saline River effectively forming a stream profile.

Water quality in the main stem of the Saline is presently at marginal levels for all parameters. Future projected mining activities throughout the Saline Basin are estimated to depress pH and net alkalinity levels to those considered critical throughout the planning period. Sulfate levels are expected to remain at marginal levels for all planning time steps.

*Single point only no table follows.

NORTH FORK SALINE

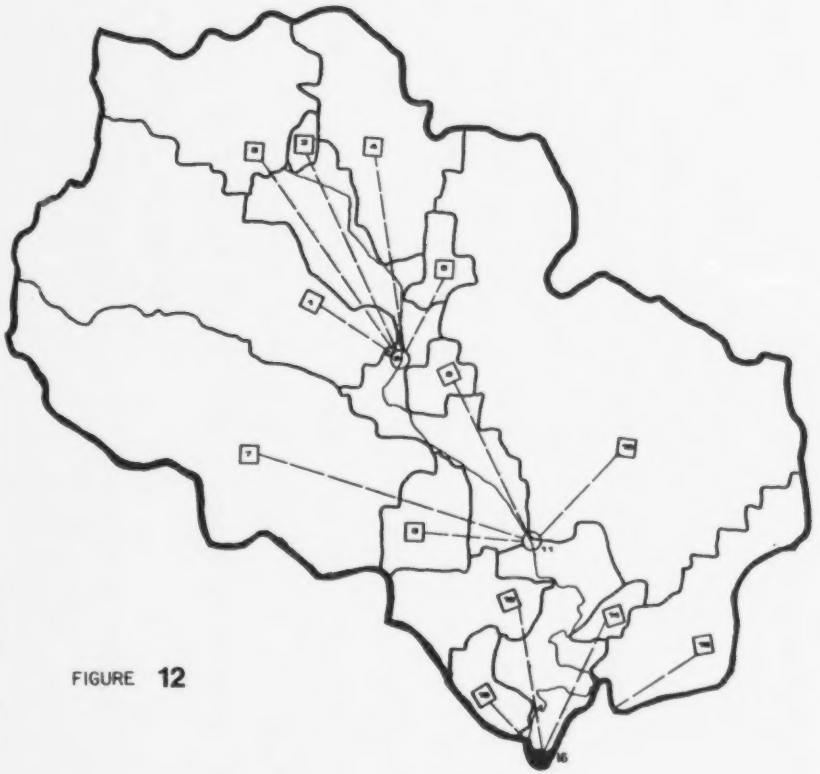
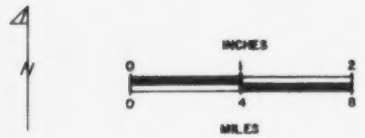


FIGURE 12



[12] MODEL NODES

● POINTS OF INTEREST

WATER QUALITY PER INTEREST POINT

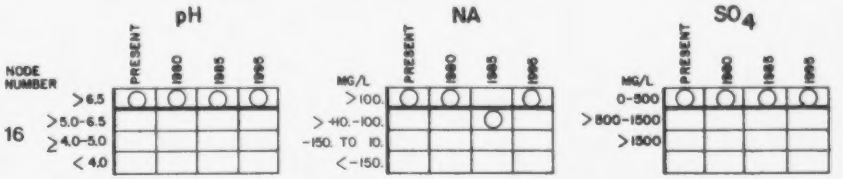


TABLE 11

LOCATIONAL DESCRIPTION OF WATER QUALITY INTEREST POINTS
MAIN STEM OF SALINE RIVER

Map Number	County	Description
1	Saline	Confluence of South Fork and Middle Fork.
5	Gallatin	Confluence of Saline River with North Fork.
8	Gallatin	Confluence of Saline River with North Fork, ½ mile East of Equality.
15	Gallatin	Confluence of Eagle Creek and Saline River.
18	Gallatin	Confluence of Beaver Creek and Saline River.

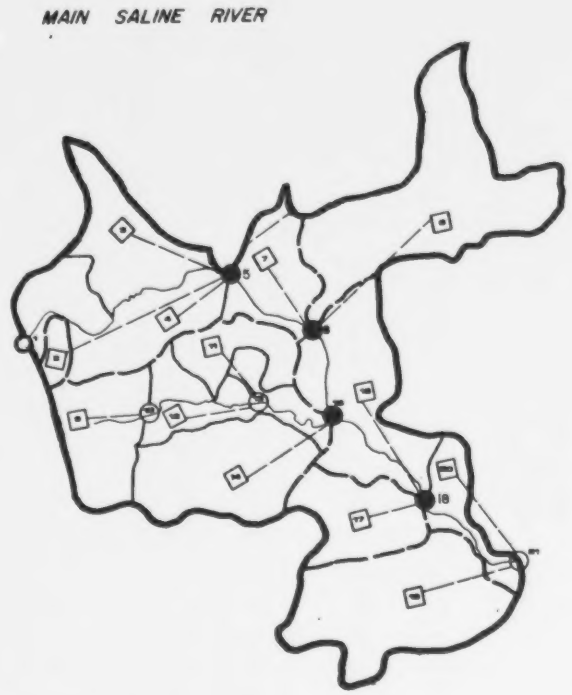
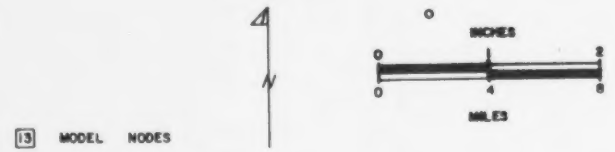
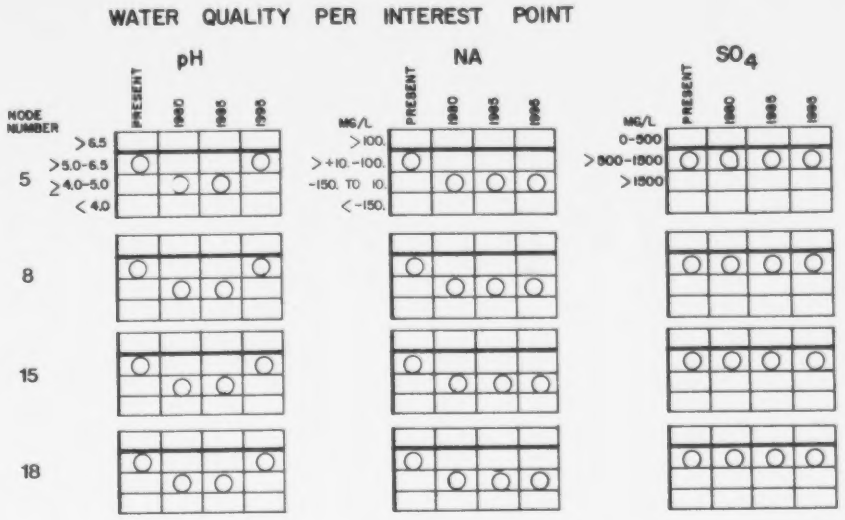

MAIN SALINE RIVER
5
8
15
18

FIGURE 13


INCHES
0
2
0
4
8
MILES
13 MODEL NODES
POINTS OF INTEREST


WATER QUALITY PER INTEREST POINT
pH
NA
SO4
NODE NUMBER
MG/L
PRESENT
1980
1985
1995
>6.5
>5.0-6.5
≥4.0-5.0
<4.0
>100.
>+10.-100.
-150. TO 10.
<-150.
0-500
>500-1500
>1500
5
8
15
18

Water quality conditions in the Eagle Creek watershed are presently marginal with pH levels and net alkalinity concentrations estimated to depress to critical levels during the first and second future time steps followed by a slight improvement in the final time period. The main stem of the Saline is reflective of heavy pollutant loads emanating primarily from the South Fork. Projected increased mining activities within the Middle Fork are primarily responsible for the predicted worsening of water quality in the watershed. Since the main stem is reflective of upstream conditions, water quality degradation in the South and Middle Forks will cause marked degradation along its length. Potential for improvement will be discussed in detail in the next section.

F. Summary of Water Quality Assessments in the Saline River Basin

Water quality levels in the North Fork of the Saline are presently at desirable levels and are estimated to only degrade slightly in the future as a result of projected mining activities in the lower portion of the catchment area. Water quality in the Bankston Fork catchment area within the Middle Fork subbasin is presently at acceptable levels. The waters of the Middle Fork further downstream are presently at acceptable water quality levels. Projected future mining development is estimated to degrade drastically water quality conditions throughout the entire Middle Fork. Water quality conditions in the South Fork are extremely critical except for the headwaters of the watershed. The mid (after input from Sugar Creek) and lower portions are extremely polluted from mining activity wastes. Without further reclamation, water quality throughout the entire watershed is expected to remain at critical levels throughout the planning period considered.

SECTION IV. RECOMMENDED CONTROL PROGRAM FOR ABATING ACID MINE WASTE POLLUTION IN THE BIG MUDDY AND SALINE RIVER BASINS.

A. Overview

This section deals with the development and presentation of recommended control programs for abating acid mine waste pollution within the 208 study area. The results indicate that it is realistic and economically feasible to control much of the existing acid mine waste pollution problem within the 208 boundaries.* Presently, four watersheds, Pond and Crab Orchard Creeks in the Big Muddy and the Middle and South Forks of the Saline River, are impacted by mine wastes. Future projections indicate that if no control or reclamation is imposed on old existing sources, coupled with projected mining increases that further water quality degradation will occur within these areas. Application of reclamation control of old existing sources within the highly impacted watersheds is estimated to yield significant water quality improvements to all basins; with the exception of the lower half of the South Fork of the Saline which is estimated to be degraded beyond reasonable hope of returning good water quality under any level of abandoned mine waste source control. This prediction is premised on the fact that overburden characteristics in the area are sufficiently acidic,** resulting in a severe degradation of the water quality without the addition of highly concentrated discharges from "gob" and slurry areas. To date no good reclamation technique economically suitable to be used on a large scale has been developed for acid spoil conditions.[39,40,41] Several experimental programs exist as exemplified by the Palzo Project along Sugar Creek within the watershed.[40,41,42,43,44,45,46,47] Although results at Palzo seem potentially promising, discharges from the area still cause extreme pH depression. In the long

*The justification for this statement is presented later in this and the following section and again in more detail in the Technical Report, Volume II of this series.

**Large scale control of orphaned spoil areas was considered in this analysis to be beyond the technical and financial capabilities of the area. This hypothesis was reiterated by representatives of the major coal companies during the 208 program. Upgrading of water quality in the lower South Fork of the

term the methodology may prove successful, but as of this time the results have not shown significant water quality enhancement.

Large sectors of the Big Muddy River watershed will suffer water quality degredation with respect to sulfates due to emissions resulting from present and future mining activities. Since the high sulfates yield is a function of the degree of exposure of large amounts of naturally occurring limestone to acid mine drainage, it is considered uncontrollable beyond the limits of present reclamation techniques. With increased mining activity, much of the Beaucoup Creek basin will contain sulfates concentrations far in excess of U.S. Public Health Service drinking water standards.* Mining at an increased level in the headwaters of Crab Orchard Lake will result in a significant rise in sulfate levels within the lake beyond acceptable limits under any level of control of old existing mine wastes.

Significant** water quality improvements may be made in Pond and Crab Orchard Creeks as well as the Middle and South Forks of the Saline Rivers if high levels of reclamation are imposed. The results are discussed in detail in Subsection E of this section.

Saline River would require extensive spoil bank control of old sources. For this reason the area was considered to be degraded beyond feasible control.

*This is not to say that the authors feel that drinking water standards should necessarily be imposed on the Southern Illinois streams. The number is simply a reference point of common familiarity used in the absence of any regulatory target or fixed standards within the area.

**Significant to levels previously described. In the case of the South Fork of the Saline significant improvements do not mean improvements to a desirable level of water quality, but merely improvements great enough to most probably allow for increased diversity of aquatic species in the watershed.

B. Cost Estimation Model

A specialized cost estimation procedure was used for analyzing various control option costs for the various surface and underground mine waste sources considered to be controllable to some degree. As mentioned in the prior section, three control options for the reduction of existing "gob" and slurry emissions were considered to be viable including: backfilling and blind flushing into abandoned underground mines; disposal into active mine strip pits, and runoff collection and containment in retention reservoirs that could be coupled with a treatment facility,* if necessary. Costs used in the analysis were generated from a careful review of available literature tempered to reflect Southern Illinois conditions, as well as actual reclamation data supplied to the 208 project by the Illinois Abandoned Mined Land Reclamation Council, IEPA and major coal companies. The final cost numbers so derived should be quite realistic and appropriate for reclamation cost estimation within the 208 area.

Basic information used in the cost analysis for each of the three methods deemed potentially feasible for controlling underground and surface "gob" and/or slurry sites was initially tabulated from maps and inventory information. Transportation distances for each option considered were determined as the radial or straightline distance from the mining site to the control point. Since these distances were straightline distances and not actual road miles, the distances were doubled for the backfill and blind flush and active pit disposal options to more reaslitically account for actual haulage.

Each mine was examined for the feasibility of secondary recovery of coal from the "gob" prior to control. If a "gob" and/or slurry site was

*In this analysis treatment facility costs were not considered. The authors are fully aware of the fact that precipitation exceeds evaporation within the area negating true evaporation pond concepts. It might be possible however, to allow controlled emissions from containment ponds during high flow periods to maintain water levels without incurring the high cost of treatment, especially with lime, which if used could simply exchange an acid problem for a sulfates and hardness problem.

determined as feasible for secondary recovery, then its estimated volume was reduced by 20 percent prior to control.

For the backfill/blind flush and active pit disposal options it was assumed that slurry areas would be backfilled in place where feasible and graded. Slurry was therefore not transported to backfill and blind flush and/or active pit disposal sites.

Volumes of "gob" buried in the active pit disposal option were considered in the following manner. First of all, the acreages of projected mining were tabulated per node per planning time step. Secondly, the volumes available for disposal per model node for each planning time step were computed by assuming that 4.0 feet and 1.0 feet of "gob" could be buried in thick or thin seam mines, respectively*. The model then computed in which period gob could be placed in active pit operations and whether there was available space. The assumption was made for multi-time period mining operations that disposal would be accomplished as quickly as possible. The analysis showed that available disposal space would not be a limiting factor. Unit costs used in the computation of reclamation costs per mine are given in Table 12.

C. Reclamation Revenues from Strip Mine Bill Revisions

The 1977 Federal Law PL 95-87 provides for funds to be set aside for reclaiming past mining problems. A surtax of $0.35 per ton of coal produced from strip mining and $0.15 per ton of coal mined by underground methods is to be assessed. Portions of this money will be used for reclaiming past problems and the balance will be used to support state programs and research and development for new reclamation techniques.

The projected surface and underground coal production levels in the Southern Illinois area for the future time period considered were obtained from GERP&DC. These production levels were then multiplied by

*It was assumed that the "gob" would be disposed of under present practice to ensure no surface or underground water impact.

TABLE 12

SUMMARY OF UNIT RECLAMATION COSTS*
USED IN COST MODEL

1. "Gob" Disposal Methods		
A.	Backfill and Blind Flush	Unit Cost
	- Excavation & Disposal	$9/yd.
	- Transportation	$.25/mi/yd.
	- Site Restoration	
	Big Muddy	$2000/acre
	Saline**	$4000/acre
B.	Active Pit Disposal	
	- Excavation	$.75/yd.
	- Transportation	$.25/mi/yd.
	- Disposal	$.75/yd.
	- Site Restoration	
	Big Muddy	$2000/acre
	Saline**	$4000/acre
C.	Reservoir	
	- Site Grading	$500/acre
	- Reservoir	$.75/cubic foot
	- Conveyance Structures	$100/linear foot
2.	Restoration of Slurry Areas	
	- Big Muddy	$2000/acre
	- Saline**	$4000/acre

SOURCE: Energy and Environmental Analysis, Inc. assessment of existing data.

*Discussed in detail in Chapter 8 of the Technical Report, Volume II of this series.

**Saline river basin costs also used for Crab Orchard watershed.

the surtaxes for surface and underground coal to compute the monies generated under the federal law. Available funds for the three planning time steps are as follows: in the period between 1977-1980, 32.4 million dollars will be available; during the second planning period, 1981-1985, 40.5 million dollars will accrue and finally, during 1986-1995, 127.2 million dollars will be available. The present worth of the available dollars for the latter two planning time steps assuming a 9 percent annual inflation rate is 24.2 and 41.5 million dollars, respectively totaling roughly 98 million dollars for all three steps. Of this sum roughly 50 percent or 49 million dollars was deemed available for reclamation projects.

D. Summary of the Mine Waste Analysis Procedure

Assessing water quality for various baseline conditions (no control of present problems as discussed in the prior section) together with various levels of reclamation of old existing sources as well as costs for the various potential control alternatives is a complex process requiring a formal methodology. The overall procedure used in the Southern Illinois 208 mine waste control program is illustrated in Figure 14. Data gathering the water quality simulation models for both present and future conditions, and the cost analysis model are all described in prior sections. Basically, the mine waste analysis procedure worked as follows:

1. Inventory all pertinent land use data with particular emphasis on mine related sources and farming.
2. Develop a watershed and area breakdown of the Big Muddy and Saline River Basins into third order subdivisions of the main stems.

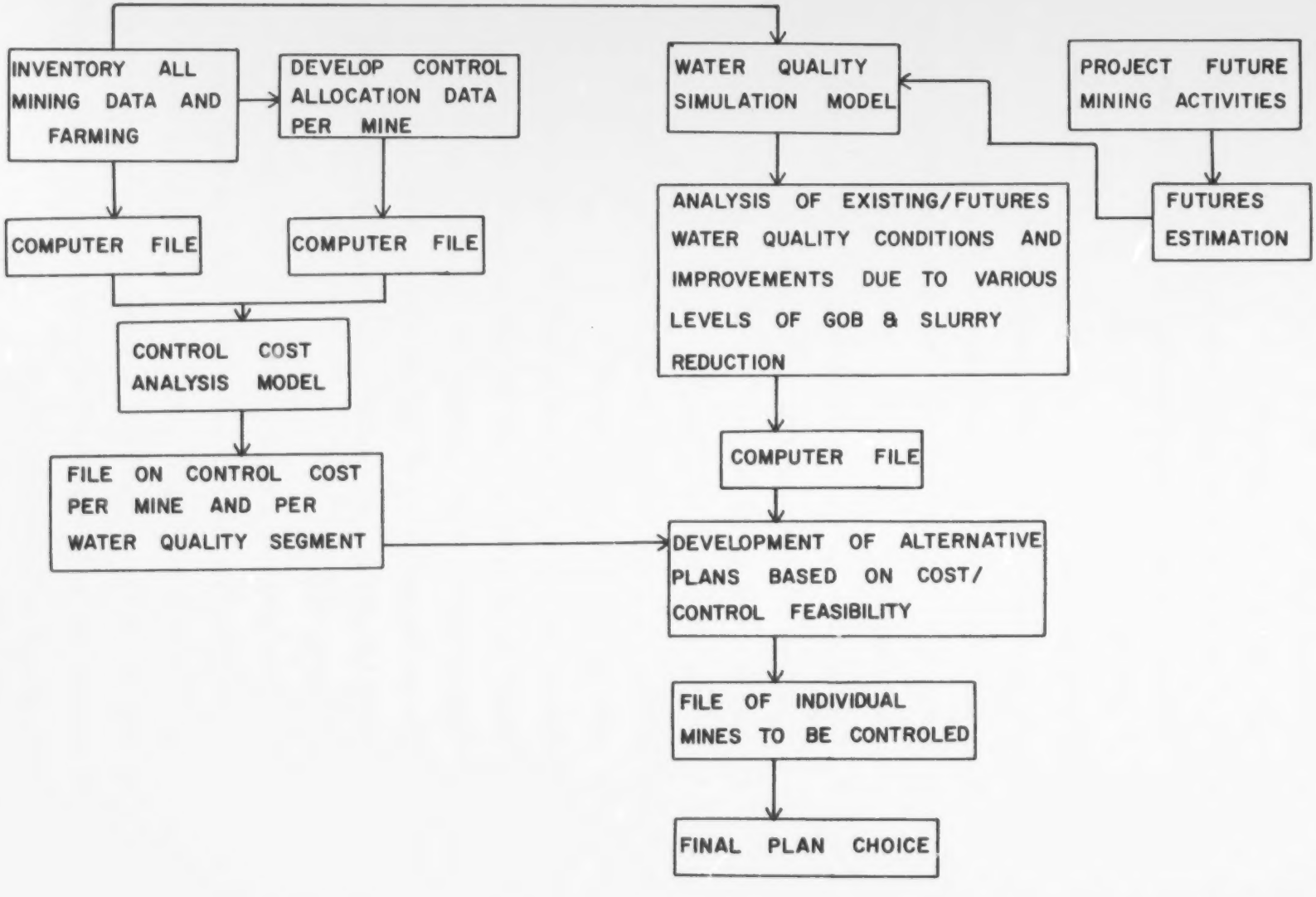

INVENTORY ALL MINING DATA AND FARMING
DEVELOP CONTROL ALLOCATION DATA PER MINE
WATER QUALITY SIMULATION MODEL
PROJECT FUTURE MINING ACTIVITIES
COMPUTER FILE
COMPUTER FILE
ANALYSIS OF EXISTING/FUTURES WATER QUALITY CONDITIONS AND IMPROVEMENTS DUE TO VARIOUS LEVELS OF GOB & SLURRY REDUCTION
FUTURES ESTIMATION
CONTROL COST ANALYSIS MODEL
COMPUTER FILE
FILE ON CONTROL COST PER MINE AND PER WATER QUALITY SEGMENT
DEVELOPMENT OF ALTERNATIVE PLANS BASED ON COST/ CONTROL FEASIBILITY
FILE OF INDIVIDUAL MINES TO BE CONTROLED
FINAL PLAN CHOICE

FIGURE 14 SUMMARY OF MINE WASTE ANALYSIS PROCEDURE

3. Locate all watershed and source data on a uniform series of maps capable of being overlayed.
4. Input all mining, farming and, watershed data into a master computer file for the water quality simulation of present conditions.
5. Develop the hydrological stream flow data file and input into the water quality simulation of present conditions.
6. Project future coal mine development and input the data per model segment per planning time step into the futures computational procedure.
7. Run the water quality simulation model to estimate present conditions for all nodes within the study area.
8. Develop a control options file for all mine waste pollution sources previously identified.
9. Develop a cost efficiency file for reclamation procedures considered viable in the analysis.
10. Run the water quality simulation model for various percent reductions of existing "gob" and slurry, establishing stream response curves to reclamation levels for each point of interest.
11. Run the futures pollution load estimation procedure for projected mining developments in each planning time step for each model node.
12. Input the additional pollutant loads in future time step per node to the water quality simulation model to project future water quality conditions with no control of existing sources.
13. Analyze the reclamation level vs water quality improvements for present and future planning time steps to derive target control levels per watershed sector.

14. Run the cost model for all controllable mine waste sources for all control options.
15. Analyze the cost vs water quality improvements/target levels for each watershed to develop alternative sets of programs meeting various water quality levels at various costs for all planning time steps.
16. Re-run the water quality simulation model to assess the performance of each of the developed plans.
17. Compare costs of the various proposed alternative plans against reclamation funds available and implementating management feasibility.
18. Choose the recommended plan.

A detailed explanation of each of the procedures used in the outlined steps is provided in the Technical Report, Volume II of this project.

One of the more difficult methodological issues faced in developing the mine waste control programs as recommended was the assessment of target water quality levels. Since there are presently no State of Illinois stream standards and use classifications for the streams of concern, no fixed standards or target values were available. This necessitated the use of a complex procedure aimed at balancing maximal water quality improvements vs minimizing program costs

The procedure used was roughly described above. In essence the water quality simulation model was run for the existing and future time steps to develop a so-called "evnironmental" or water quality baseline of conditions that would occur if no reclamation of

existing old problems was instituted. The water quality simulation model was then rerun assuming uniform levels of 25, 50, 75 and 85* percent "gob" and slurry reduction throughout all watersheds for the present conditions. These data were then coupled with the projected futures data in graphic form.

Figure 15 shows plots of projected conditions for the Middle Fork of the Saline River at node point 18 for pH, net alkalinity, and sulfates, respectively. The plots graphically display the effect of various upstream control levels of old existing mine wastes for present conditions which are shown by the solid lines. Future conditions assuming no control of existing sources are shown by the dashed lines. To assess the impact of any level of control of existing pollution, the relative improvement of a given percent reduction "gob" and slurry may simply be subtracted from the projected future level for the time of interest. In this manner, the relative changes in water quality under different projected levels of increased coal production and degrees of existing source control, were easily assessed.

Each point of interest was then listed in a file with its associated present levels of "gob" and slurry. Analyses of the curves, such as those shown in Figure 15 were generated for each point of interest in each of the eleven subbasins. From analysis of the reduction efficiency and futures projections, optimum or target control levels were generated for each watershed sector to provide the best reasonable level of control to be used in plan formulation. Once the target removal levels were established, the cost data per mine was assessed to generate the least cost control plan to attain the desired water quality levels under several assumed conditions.

*A cutoff limit of 85% removal is considered to be realistic for reclamation of old sectors.

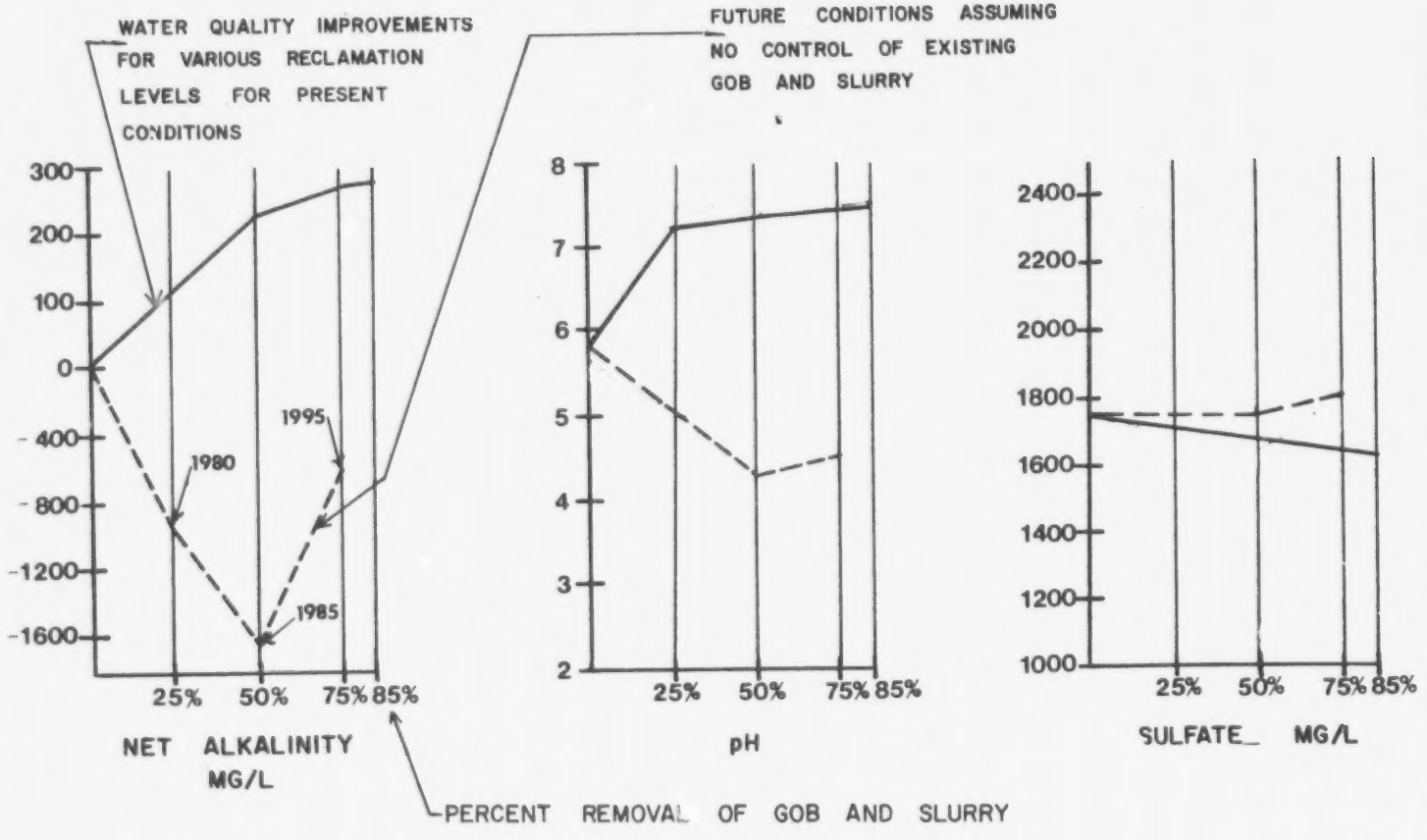


FIGURE 15

PREDICTED AVERAGE POLLUTANT LEVELS UNDER VARIOUS CONDITIONS
FOR NODE 18 OF MIDDLE FORK OF THE SALINE RIVER

The assumptions used in the analysis of mine waste controls are illustrated in Table 13.

E. Plan Selection

Analysis of water quality and control data indicates that control of existing mine waste sources of "gob" and slurry* would be limited primarily to the Pond and Crab Orchard watersheds in the Big Muddy River Basin, and the Middle and South Forks of the Saline River Basin. This statement is based on the premise that the target for water quality improvements is best controlled at a moderate cost. Other small sectors of control such as the western side of Rend Lake were considered. The value of reclamation of old abandoned mining areas west of Rend Lake is questionable in that the wastes are not causing substantial degradation of the Lake itself. For water supply protection best reasonable attainable (Plan A) levels of "gob" and slurry removal in this area might be worthwhile. Analysis of the area indicates that a total of 21 sources would have to be reclaimed costing, using the Plan A approach, approximately 6.5 million dollars. Water quality levels in all other areas were considered to be presently acceptable for controllable pollutants, primarily pH and net alkalinity. Sulfates control was found to be possible only where "gob" and slurry formed the primary production of sulfates.** Control of residual pollutants beyond present reclamation*** levels for active and future mining operations was not considered to be technically or economically feasible at this point. Even though present mining operations result in very low pollutant discharge levels as compared to past operations, the cumulative effect of the emissions based on projected production will cause severe uncontrollable water quality degradation in several sectors of the area, especially with respect to sulfate concentrations

* Primarily old abandoned waste.

** The concept here being that much of the $SO_4^{=}$ ion is coming from the acid produced from "gob" and slurry waste oxidation. In areas where "gob" and slurry form the majority of the acid production vs acidic overburden, removal of the "gob" and slurry will remove the primary source of acid and ultimately, sulfates from conversion due to neutralization reactions.

*** Reclamation level as specified by PL 95-87.

TABLE 13

DESCRIPTION OF ALTERNATIVE AREAWIDE RECLAMATION PLANS
FOR CONTROL OF EXISTING GOB AND SLURRY PROBLEMS

	Description
Plan A	- Best attainable water quality in Pond and Crab Orchard Creeks, Big Muddy Basin; and in the Middle and South Fork of Saline Basin. - Subsidence control with a 2 mile radius of population centers if reasonable* and least cost method chosen otherwise.
Plan B	- Complete elimination of "gob" and slurry in Pond and Crab Orchard Creeks, Big Muddy Basin; and in the Middle and South Fork of Saline. - Subsidence control with a 2 mile radius of population centers regardless of cost and least cost method chosen otherwise.
Plan C	- Complete elimination of "gob" and slurry in Pond and Crab Orchard Creeks, Big Muddy Basin; and in the Middle and South Fork of Saline. - Least cost method of control chosen per mine.
Plan D	- Best attainable water quality in Pond and Crab Orchard Creeks, Big Muddy Basin; and in the Middle and South Fork of Saline Basin. - Least cost method of control chosen per mine.

*Reasonable as defined was a unit cost not to exceed two times that of the least expensive alternative.

as previously described.

Plan A represents the best reasonable attainable water quality as defined by the analysis of the water quality vs control level curves using backfilling and blind flushing as a preferred method around population centers and the least cost method otherwise.* Backfilling and blind flushing was considered to be preferrable and economically realistic around population centers because it represented dual benefits: 1) reduction of mining pollutants, 2) some measure of subsidence control. Plan B represents 100% "gob" and slurry control of existing sources coupled with subsidence** control around all population centers. Plan C represents a level of 100% control throughout each basin using the least cost method. Plan D represents the best reasonable, attainable water quality levels as defined by Plan A coupled with the least cost control alternatives.

Table 14 is a summary of the total program cost for each of the four basins where control was considered worthwhile for each of the four control plans. Our analysis indicates Plan A, best reasonable water quality control with subsidence control to be by far the most cost effective method considering additional benefit of subsidence control in population centers. The best reasonable control level represents roughly 50 percent "gob" and slurry removal from the Pond Creek watershed, 50 percent removal from the Crab Orchard Creek watershed, 85 percent control in the South Fork of the Saline River and 50 percent control in the Middle Fork of the Saline. Further reductions beyond this point produce increases in cost totally disproportionate to improved water quality levels, and were not considered to be justifiable for recommendation. Table 15 presents a detailed breakdown of mine waste locations, "gob" and slurry areas and method of each control option for each mine within the four watersheds where control is recommended. Subtotal costs

*See Table 13.

**In this plan subsidence control was considered without regard to cost for the 2 mile radius around population centers.

TABLE 14

SUMMARY OF RECLAMATION COSTS PER PLAN

	Plan A	Plan B	Plan C	Plan D
Pond Creek	2,599,700	11,376,100	7,734,200	2,582,300
Crab Orchard Creek	436,900	3,757,300	1,227,500	398,600
South Fork Saline	3,536,100	4,818,900	4,818,900	3,536,100
Middle Fork Saline	4,995,900	12,265,900	12,265,900	4,995,900
Totals*	$11,568,600	$32,218,200	$26,046,500	11,512,900

*Numbers may not add exactly due to rounding off.

TABLE 15

*** SHAWNEE TYPE REGIONAL PLANNING & DEVELOPMENT COMMISSION ***

SOUTHERN ILLINOIS 208 AREAWIDE WASTE PROGRAM
SUMMARY OF MINE WASTE RECLAMATION PROGRAM
(ALL COSTS IN $1000'S)

Reproduced from best available copy.

BASIN NAME	MAP REF.	D/S	MINE DESCRIPTION	SOA (AC.)	SLURRY (AC.)	PLAN A COST	PLAN A METHOD	PLAN B COST	PLAN B METHOD	PLAN C COST	PLAN C METHOD	PLAN D COST	PLAN D METHOD
P	150	D	ZEIGLER #4	95.1	93.5	862.1	B	862.1	B	862.1	B	862.1	B
P	152	D	OLD MINE #9	98.0	23.7			3305.0	B	3305.0	B		
P	153	D	OLD BOB #15	137.0	0.0	767.6	B	767.6	B	767.6	B	767.6	B
P	64	D	PEABODY COAL COMPANY	6.9	0.0			6.6	B	6.6	B		
P	66	D	BLACK BEAR MINE	0.5	0.0	1.9	B	4.5	A	1.9	B	1.9	B
P	67	D	INDEPENDENT SMALL COAL CO.	0.2	0.0	0.8	B	2.8	A	0.8	B	0.8	B
P	73	D	...E BUN COAL COMPANY	20.9	0.0	47.2	B	61.2	A	47.2	B	47.2	B
P	74	D	OLD BOB COAL COMPANY	2.6	0.0	4.3	B	4.9	A	4.3	B	4.3	B
P	77	D	ST. BONIS COAL & COKE	14.3	0.0	35.7	B	59.2	A	35.7	B	35.7	B
P	126	D	ZEIGLER #4	44.3	33.3	514.9	B	1368.3	A	514.9	B	514.9	B
P	75	D	PEABODY COAL COMPANY #3	2.9	0.0			56.9	A	16.0	B		
P	78	D	CRESSMAN-FREEMAN COAL CO.	3.0	0.0	23.4	A	23.4	A	12.2	B	12.2	B
P	119	D	INDEPENDENT SMALL COAL CO.	1.4	0.0	13.0	A	13.2	A	6.8	B	6.8	B
P	124	D	ZEIGLER #3	32.2	3.6			2302.0	A	814.0	B		
P	57	D	* CHIC/WIL/PEABODY COAL CO	35.6	0.0			788.8	B	788.8	B		
P	134	D	* CONSOLIDATED OF ST. LOUIS	9.2	0.0			334.8	A	88.4	B		
P	141	D	ZEIGLER #7	9.2	0.0			226.8	A	64.4	B		
P	142	D	* PEABODY COAL CO.	3.2	0.0			131.6	A	44.4	B		
P	52	S	* FORSYTHE ENERGY	3.0	0.0			100.2	A	24.3	B		
P	52	S	FORSYTHE ENERGY	26.0	58.0	328.8	B	986.6	A	328.8	B	328.8	B
			SUBTOTAL:			2599.7		11376.1		7734.2		2582.1	
CO	56	D	KEYSTONE #285	5.2	0.0	24.6	A	24.6	A		B	25.8	B
CO	64	D	SCHULLS SOAKS MINE	1.9	0.0	9.9	B	21.4	A	9.9	B	9.9	B
CO	65	D	SCRANTON MINE	6.4	0.0	35.3	A	35.3	A	27.2	B	27.2	B
CO	133	D	INDEPENDENT SMALL COAL CO.	1.0	0.0	9.8	A	9.8	A	5.3	B	5.3	B
CO	135	D	* INDEPENDENT SMALL COAL CO.	3.2	0.0	19.0	A	19.0	A	13.2	B	13.2	B
CO	70	D	PICKFORD MINE	1.4	0.0			26.3	A	3.0	B		
CO	80	D	KNIGHT-PORGES	2.2	0.0	21.6	A	21.6	A	11.3	B	11.3	B
CO	72	D	BLACK DIAMOND	4.8	0.0			154.2	A	44.7	B		
CO	63	S	* ASSOCIATED COAL CO.	4.0	0.0			150.0	A	36.9	B		
CO	111	D	TAYLOR BROTHERS	12.9	0.6			571.5	A	153.6	B		
CO	117	D	... BLACK DIAMOND COAL CO.	10.9	3.3			1450.8	A	332.0	B		
CO	125	D	PEABODY COAL CO.	1.4	0.0			25.9	A	9.0	B		
CO	90	S	MORGAN UTILITY	0.0	9.0	19.0	A	19.0	A	13.2	B	13.2	B
CO	69	D	OLNE PIGEON #2	0.2	0.0			1.1	A	0.9	B		
CO	75	D	INDEPENDENT SMALL COAL CO.	0.8	0.0			4.4	A	3.4	B		
CO	76	D	DUNCAN	0.1	0.0			1.2	A	0.6	B		
CO	89	D	INDEPENDENT SMALL COAL CO.	13.5	0.0	87.0	B	255.3	A	87.0	B	87.0	B
CO	114	D	INDEPENDENT SMALL COAL CO.	0.6	0.0			11.2	A	4.1	B		
CO	62	D	INDEPENDENT COAL COMPANY	1.7	0.0			12.0	C	12.0	P		
CO	115	D	SQUARE DEAL MINE	6.6	0.0	36.8	B	36.8	P	36.8	B	36.8	B
CO	116	D	D AND J MINE	4.4	0.0			53.6	B	53.6	B		
CO	68	D	CHICAGO-WILL COUNTY COAL CO.	3.7	0.0			59.2	B	59.2	B		
CO	46	S	FORSYTHE CENTRALIA	7.2	0.0			254.0	A	67.1	B		
CO	110	D	...BOGAINS MINE	0.6	0.0			4.1	B	4.1	B		
CO	91	S	UTILITY COMPANY	8.0	25.0	173.9	B	390.3	A	173.9	B	173.9	B

METHODS :
A = BACKFILLING AND REGRADING INTO ADJACENT DEEP-MINE AND STRIP MINES.
B = DISPOSAL INTO ACTIVE STRIP MINING OPERATIONS.
NUMBERS REFER TO PLANNING TIME STEP WHEN DISPOSAL CAN OCCUR.
C = RUNOFF CAPTURE AND DETENTION IN IMPOUNDMENT.

*Data indicates that these sources may be partially or totally reclaimed. Removal efficiency unknown.

TABLE 15 Cont.

*** SOUTHERN ILLINOIS REGIONAL PLANNING & DEVELOPMENT COMMISSION ***

SOUTHERN ILLINOIS 2.8 AMENDED MINE WASTE PROGRAM
SUMMARY OF MINE WASTE RECLAMATION PROGRAM
(ALL COSTS IN $1000'S)

BASIN NAME	MINE REF.	O/S	MINE DESCRIPTION	JOB (AC.)	SLURRY (AC.)	PLAN A COST	PLAN A METHOD	PLAN B COST	PLAN B METHOD	PLAN C COST	PLAN C METHOD	PLAN D COST	PLAN D METHOD
CO	89	U	TAB MINE	0.5	0.0			3.6	B	3.6	B		
CO	91	U	INDEPENDENT SMALL COAL CO.	0.5	0.0			3.2	B	3.2	B		
CO	92	U	INDEPENDENT SMALL COAL CO.	3.0	0.0			17.1	B	17.1	B		
CO	93	U	INDEPENDENT SMALL COAL CO.	2.0	0.0			14.8	B	14.8	B		
			SUBTOTAL:			436.9		3757.3		1227.5		398.6	
SF	76	S	AMAX C-C DELTA MINE	83.0	3.0	226.4	B	226.4	B	226.4	B	226.4	B
SF	80	U	CHANEY & CRESHAM	1.6	0.0	9.1	B	9.1	B	9.1	B	9.1	B
SF	85	U	OAK GROVE	4.1	0.0	27.0	B	27.0	B	27.0	B	27.0	B
SF	86	U	STEELE PEARLE	1.8	0.0	11.8	B	11.8	B	11.8	B	11.8	B
SF	87	U	INDEPENDENT SMALL COAL CO.	1.9	0.0	10.2	B	10.2	B	10.2	B	10.2	B
SF	88	U	CIRCLE COAL COMPANY	4.0	0.0	23.4	B	23.4	B	23.4	B	23.4	B
SF	90	S	CHERRY HILL	5.5	0.0	34.2	B	34.2	B	34.2	B	34.2	B
SF	93	U	* ADDRE MINE	5.9	0.0	84.4	B	84.4	B	84.4	B	84.4	B
SF	96	U	COLE HILL	5.7	0.0	53.0	B	53.0	B	53.0	B	53.0	B
SF	97	U	WALNUT VALLEY	1.6	0.0	8.6	B	8.6	B	8.6	B	8.6	B
SF	104	U	LIBERTY COAL CO.	1.2	0.0	6.3	B	6.3	B	6.3	B	6.3	B
SF	72	S	VALLEY COPPER MINE	3.0	0.0	28.8	B	28.8	B	28.8	B	28.8	B
SF	86	S	* PEABODY MINE	13.0	0.0	170.0	B	170.0	B	170.0	B	170.0	B
SF	86	S	PEABODY MINE	39.0	0.0	509.9	B	509.9	B	590.9	B	509.9	B
SF	103	S	* PEABODY C-C	0.0	55.0	220.0	A	220.0	A	220.0	A	220.0	A
SF	76	S	* AMAX C-C DELTA MINE	2.0	0.0			58.2	A	52.2	A		
SF	85	S	LAGLAD C-C	29.0	0.0			844.7	A	844.7	A		
SF	76	S	AMAX C-C LOWER DELTA MINE	19.0	0.0	171.5	B	171.5	B	171.5	B	171.5	B
SF	97	S	BLUEBIRD C-C	65.0	10.0	72.0	B	72.0	B	72.0	B	72.0	B
SF	97	S	BLUEBIRD C-C	7.0	0.0	207.8	A	207.8	A	207.8	A	207.8	A
SF	103	S	* PEABODY C-C	0.0	1.0	4.0	A	4.0	A	4.0	A	4.0	A
SF	112	S	BAXTON C-C	23.3	10.0			283.8	B	283.8	B		
SF	113	S	BAXTON C-C	0.0	17.0	68.0	A	68.0	A	68.0	A	68.0	A
SF	103	S	* PEABODY C-C	0.0	16.0	64.0	A	64.0	A	64.0	A	64.0	A
SF	139	U	* INDEPENDENT SMALL COAL CO.	4.4	0.0			37.8	B	37.8	B		
SF	140	U	INDEPENDENT SMALL COAL CO.	2.3	0.0			12.2	B	12.2	B		
SF	155	U	WASSON #2	0.8	0.0			3.8	B	3.8	B		
SF	140	U	WASSON #2	6.5	0.0			26.6	B	26.6	B		
SF	95	S	SAHARA C-C	41.0	71.0	284.0	B	284.0	B	284.0	B	284.0	B
SF	97	S	BLUEBIRD C-C	24.0	16.0	64.0	B	64.0	B	64.0	B	64.0	B
SF	96	S	SAHARA C-C	37.0	0.0	1077.7	A	1077.7	A	1077.7	A	1077.7	A
SF	140	U	INDEPENDENT SMALL COAL CO.	2.0	0.0			15.7	A	15.7	A		
SF	103	S	PEABODY COAL CO.	54.0	27.0	100.0	B	100.0	B	100.0	B	100.0	B
			SUBTOTAL:			3536.1		4818.9		4818.9		3536.1	
MS	75	S	AMAX DELTA MINE	1.0	0.0			8.2	B	8.2	B		
MS	76	S	BLUEBIRD	3.9	2.0	33.5	B	33.5	B	33.5	B	33.5	B
MS	76	S	* AMAX DELTA MINE	28.0	0.0			307.4	B	307.4	B		
MS	74	S	* TRINITY RESOURCES MINE	3.0	29.0	142.7	B	142.7	B	142.7	B	147.7	B
MS	76	S	* AMAX DELTA MINE	0.0	20.0	80.0	B	80.0	A	80.0	A	80.0	B
MS	62	U	A.O. SCHMOOL	5.7	0.0			60.9	A	60.9	A		

METHODS :
A = BACKFILLING AND BLINDFLUSHING INTO ABANDONED UNDERGROUND MINES.
B = DISPOSAL INTO ACTIVE STRIP MINING OPERATIONS.
NUMBERS REFER TO PLANNING TIME STEP WHEN DISPOSAL CAN OCCUR.
C = RUNOFF CAPTURE AND DETENTION IN BASIN/LIF.

*Data indicates that these sources may be partially or totally reclaimed. Removal efficiency unknown.

TABLE 15 Cont.

*** GREATER EGYPT REGIONAL PLANNING & DEVELOPMENT COMMISSION ***

SOUTHERN ILLINOIS 208 AREAWIDE MINE WASTE PROGRAM
SUMMARY OF MINE WASTE RECLAMATION PROGRAM
(ALL COSTS IN $1000'S)

BASIN NAME	MINE REF.	U/S	MINE DESCRIPTION	SOB (AC.)	SLURRY (AC.)	PLAN A COST	PLAN A METHOD	PLAN B COST	PLAN B METHOD	PLAN C COST	PLAN C METHOD	PLAN D COST	PLAN D METHOD
MS	83	U	ENSINGER	0.5	0.0			1.4	B	1.4	B		
MS	91	U	INDEPENDENT SMALL COAL CO.	0.3	0.0			1.7	B	1.7	B		
MS	94	U	INDEPENDENT SMALL COAL CO.	3.1	0.0	20.8	B	20.8	B	20.8	B	20.8	B
MS	100	U	GREAT VALLEY	2.9	0.0			28.8	B	28.8	B		
MS	101	U	GREAT VALLEY	0.1	0.0			0.5	B	0.5	B		
MS	113	U	INDEPENDENT SMALL COAL CO.	1.8	0.0	17.7	A	17.7	A	17.7	A	17.7	A
MS	120	U	NEW SUBERIOR	1.3	0.0	6.0	B	6.0	B	6.0	B	6.0	B
MS	123	U	TURLEY #1	4.7	1.1			93.1	B	93.1	B		
MS	132	U	HARRISBURG #1	29.0	0.0			844.7	A	844.7	A		
MS	81	S	AMAX DELTA MINE	6.0	0.0			70.1	B	70.1	B		
MS	78	S	AMAX DELTA MINE	2.0	0.0			27.5	B	27.5	B		
MS	99	U	INDEPENDENT SMALL COAL CO.	5.6	0.0	36.9	B	36.9	B	36.9	B	36.9	B
MS	94	S	SAHARA C-C	20.0	11.0	249.6	B	249.6	B	249.6	B	249.6	B
MS	96	S	SAHARA C-C	218.0	140.0	3277.1	B	3277.1	B	3277.1	B	3277.1	B
MS	96	S	SAHARA C-C	9.0	6.0	110.3	B	110.3	B	110.3	B	110.3	B
MS	94	S	SAHARA C-C	42.0	10.0	489.4	B	489.4	B	489.4	B	489.4	B
MS	96	S	SAHARA C-C	34.0	10.0	143.6	B	143.6	B	143.6	B	143.6	B
MS	162	U	*PEABODY #43	26.7	0.0			752.2	C	752.2	C		
MS	163	U	PEABODY #40	3.6	0.0			223.2	A	223.2	A		
MS	164	U	PEABODY #40	93.5	0.0	388.3	A	388.3	A	388.3	A	388.3	A
MS	96	S	* SAHARA C-C	14.0	0.0			138.1	B	138.1	B		
MS	150	U	*PEABODY #47	117.3	0.0			3795.6	B	3795.6	B		
MS	157	U	*SAHARA #10	31.2	0.0			131.2	B	131.2	B		
MS	149	U	INDEPENDENT SMALL COAL CO.	1.0	0.0			5.2	B	5.2	B		
MS	153	U	*SAHARA COAL CO.	9.0	0.0			50.5	B	50.5	B		
MS	154	U	*SAHARA COAL CO.	1.0	0.0			5.6	B	5.6	B		
MS	151	U	O'GARA #12	22.0	0.0			110.0	B	110.0	B		
MS	152	U	O'GARA #12	5.6	0.0			166.4	B	166.4	B		
MS	159	U	*WASSON #1	17.5	0.0			84.1	B	84.1	B		
MS	161	U	O'GARA #1	10.6	0.0			49.2	B	49.2	B		
MS	158	U	*BANKSTON CREEK COAL CO.	4.0	0.0			20.7	B	20.7	B		
MS	116	S	BANKSTON CREEK COLLERIES	10.0	0.0			292.7	A	292.7	A		
MS	79	S	AMAX DELTA MINE	2.0	0.0			70.1	B	70.1	B		
MS	111	S	BLUEBIRD COAL CO.	7.0	0.0			.0	B	9.0	B		
			SUBTOTAL:			4995.9		12265.9		12265.9		4995.9	

METHODS :
A = BACKFILLING AND BLINDFLUSHING INTO ABANDONED UNDERGROUND MINES.
B = DISPOSAL INTO ACTIVE STRIP MINING OPERATIONS.
NUMBERS REFER TO PLANNING TIME STEP WHEN DISPOSAL CAN OCCUR.
C = RUNOFF CAPTURE AND DETENTION IN RESERVOIR.

*Data indicates that these sources may be partially or totally reclaimed. Removal efficiency unknown.

per plan for each subbasin are tabulated. This table pinpoints exact sources as they are best known from available data selected for control.* It is possible, in some cases, to choose different combinations of mine waste sources to control and attain similar water quality levels within a given watershed. As previously stated the recommended plan is based on least cost considerations and not political feasibility.** Figures 16, 17, 18 and 19 represent the expected water quality resultant from Plan A in the Pond, Crab Orchard Creeks and Middle and South Forks respectively. The cost of the recommended plan, Program A, are well under the available monies established by provisions of the Federal Strip Mining Bill.

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*Locations of all sources are shown on the mine locational maps presented in Volume III, Maps of the series.

**Screening the political and technical feasibility of control on a case by case basis was never the intent or scope of this study. The recommended Plan is a combination or reductions aimed at improving water quality to a maximal realistic level without undo increases in program cost. If the areas suggested were to be reclaimed a technical feasibility study would have to be conducted on each mine and possibly alternates chosen.

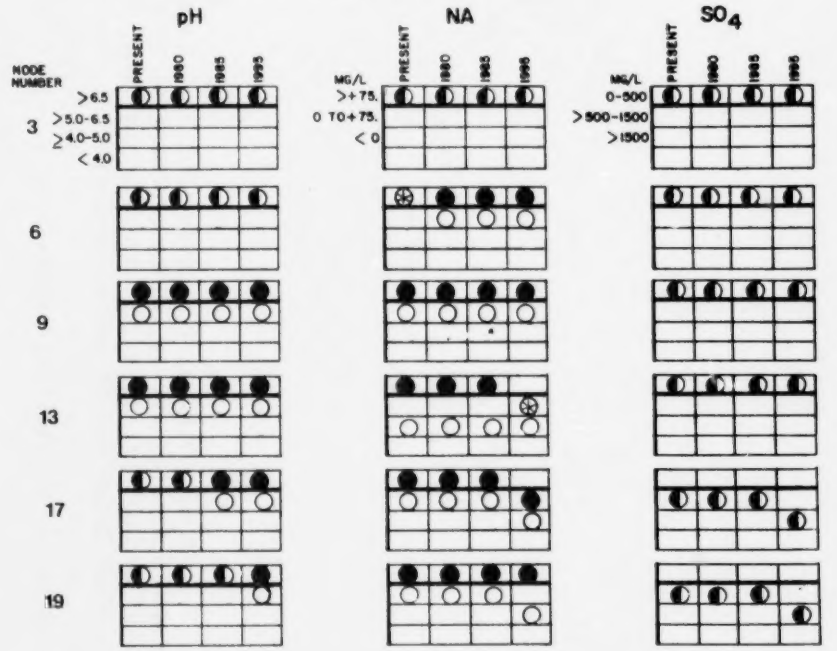
A COMPARISON OF EXPECTED WATER QUALITY CONDITION BETWEEN NO RECLAMATION AND PLAN A

FIGURE 16

[14] MODEL NODES

● POINTS OF INTEREST

WATER QUALITY PER INTEREST POINT



○ PREDICTED WATER QUALITY WITH NO CONTROL OF EXISTING SOURCES

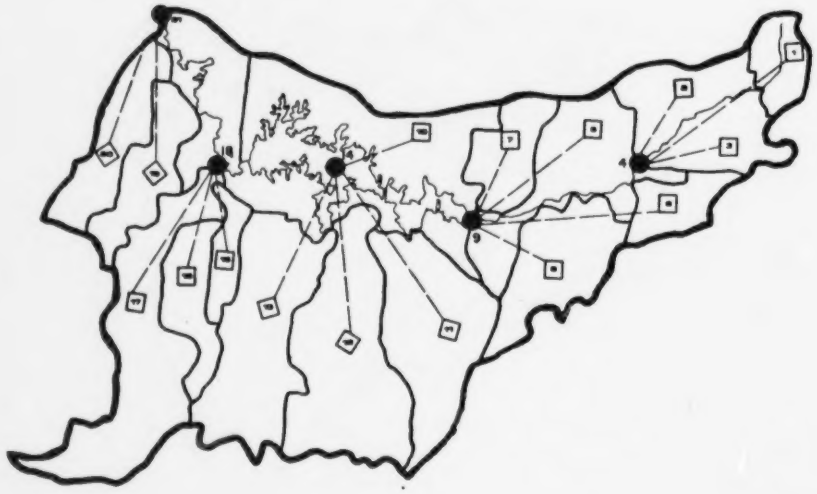
● WATER QUALITY WITH CONTROL AS PER PLAN A

◐ NO CHANGE IN WATER QUALITY

⊛ MARGINAL CHANGE IN WATER QUALITY, NOT ENOUGH TO IMPROVE TO NEXT LEVEL

CRAB ORCHARD CREEK

A COMPARISON OF EXPECTED WATER QUALITY CONDITION BETWEEN NO RECLAMATION AND PLAN A



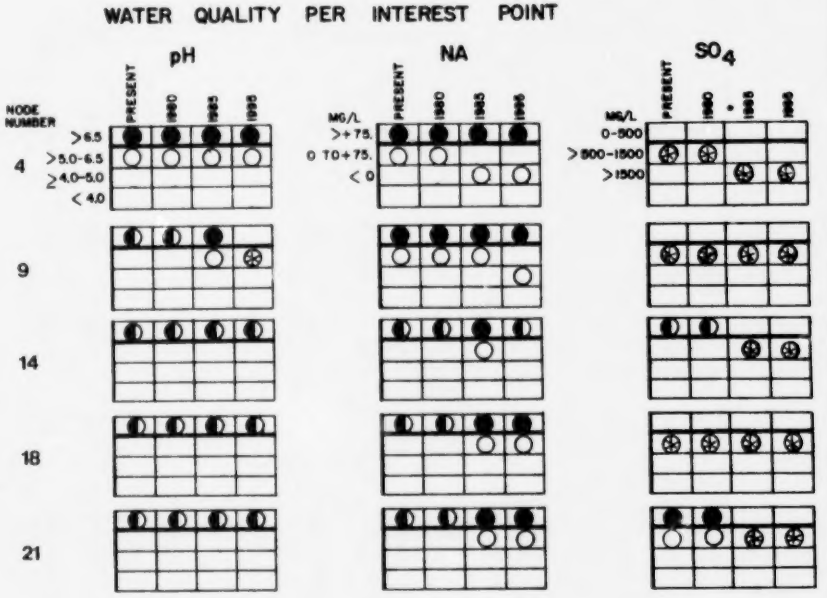


FIGURE 17

17 MODEL NODES

POINTS OF INTEREST

○ PREDICTED WATER QUALITY WITH NO CONTROL OF EXISTING SOURCES

● WATER QUALITY WITH CONTROL AS PER PLAN A

◐ NO CHANGE IN WATER QUALITY

⊛ MARGINAL CHANGE IN WATER QUALITY, NOT ENOUGH TO IMPROVE TO NEXT LEVEL

A COMPARISON OF EXPECTED WATER QUALITY CONDITION BETWEEN NO RECLAMATION AND PLAN A

MIDDLE FORK SALINE

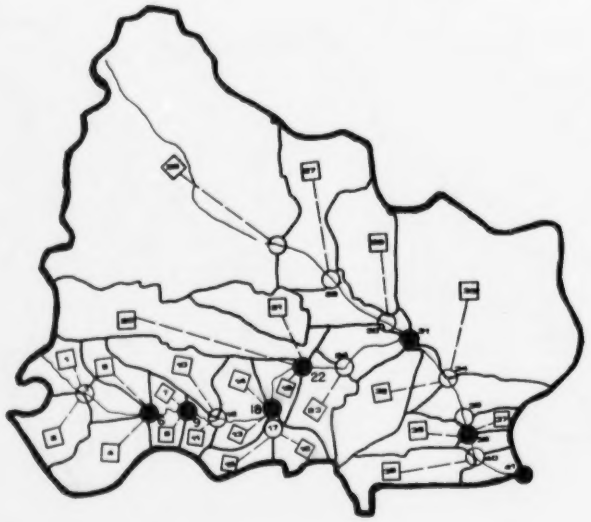
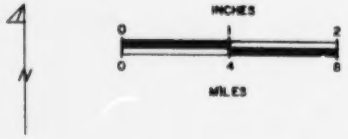


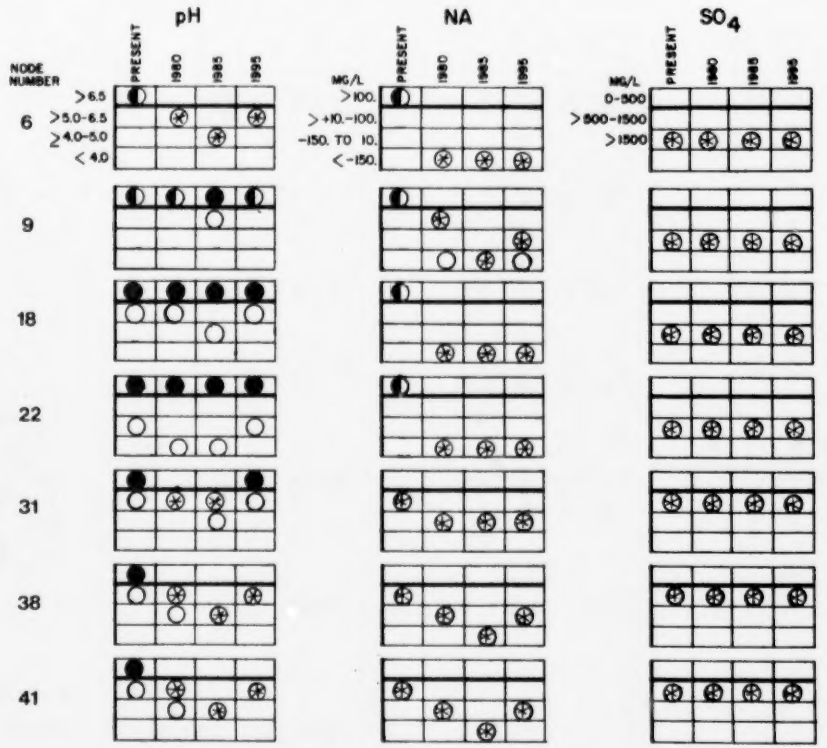
FIGURE 18



[21] MODEL NODES

● POINTS OF INTEREST

WATER QUALITY PER INTEREST POINT



○ PREDICTED WATER QUALITY WITH NO CONTROL OF EXISTING SOURCES

● WATER QUALITY WITH CONTROL AS PER PLAN A

◐ NO CHANGE IN WATER QUALITY

⊛ MARGINAL CHANGE IN WATER QUALITY, NOT ENOUGH TO IMPROVE TO NEXT LEVEL

A COMPARISON OF EXPECTED WATER QUALITY CONDITION BETWEEN NO RECLAMATION AND PLAN A

SOUTH FORK SALINE

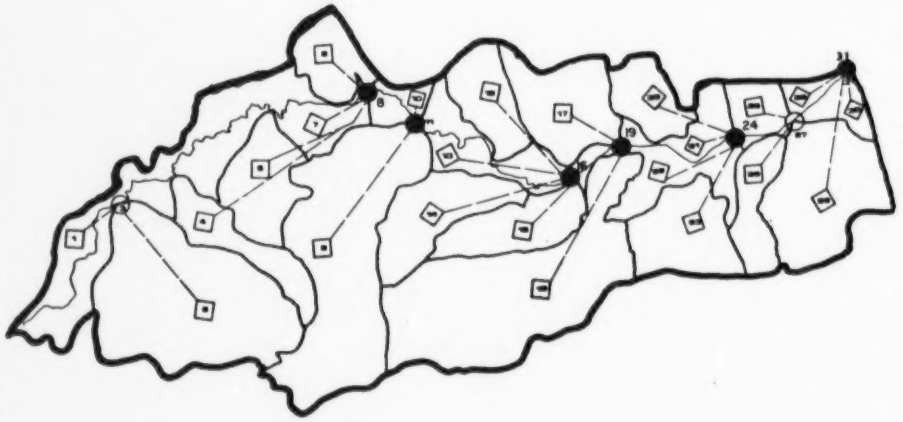
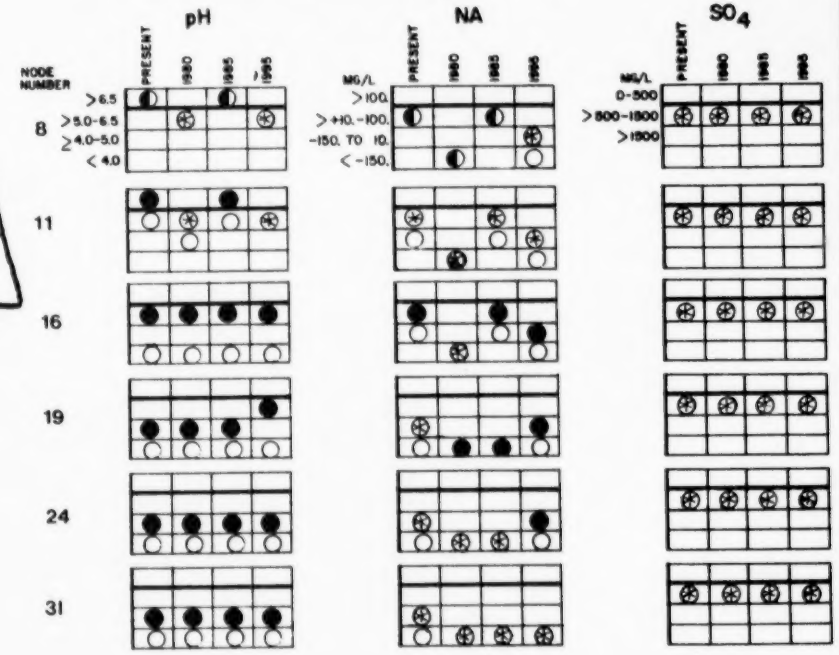
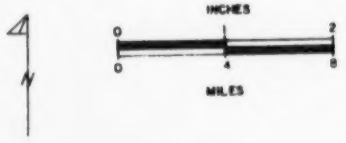


FIGURE 19

WATER QUALITY PER INTEREST POINT





21 MODEL NODES

POINTS OF INTEREST

○ PREDICTED WATER QUALITY WITH NO CONTROL OF EXISTING SOURCES

● WATER QUALITY WITH CONTROL AS PER PLAN A

◐ NO CHANGE IN WATER QUALITY

⊛ MARGINAL CHANGE IN WATER QUALITY, NOT ENOUGH TO IMPROVE TO NEXT LEVEL

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